OTONABEE RIVER - RICE LAKE

SEDIMENT AND BIOMONITORING

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Executive Summary

A number of studies undertaken by both provincial and federal agencies since the mid-1970's in the Otonabee River and Rice Lake, downstream of the City of Peterborough have found PCBs in water, sediments and biota. Fish consumption restrictions have been in place for certain fish species from Rice Lake since the mid-1980's. Most of the studies conducted to date have identified storm sewer discharges that drain from two primary potential users of PCBs to the system as the major sources.

Based on the results of these earlier studies, the Ministry undertook a detailed investigation of sediment contamination, and resultant biological effects in 1996. The study involved a number of study components designed to assess the impacts of sediment contamination, as well as the potential effects of any on-going sources. Sediment samples were collected to determine the extent of sediment contamination, both with depth, which gave a historical perspective on sediment contamination by PCBs and longitudinally within the Otonabee River. Since Rice Lake has been extensively sampled by both the Ministry and Environment Canada, additional sampling was not undertaken in this area. The biological effects of sediment contamination were measured using laboratory sediment bioassays, as well as information collected as part of the Young-of-the-year Fish Monitoring Program and the Sport Fish Contaminant Monitoring Program. The effects of current discharges through the storm sewers were measured using caged mussels. Mussels feed by filtering the water column for particulate matter. In the course of their feeding they will incorporate contaminants in the water column into their body tissues, thereby providing an excellent means of assessing discharges of contaminants over time.

The study found that PCBs were broadly distributed throughout the Otonabee River- Rice Lake system, from Peterborough through to the outlet of Rice Lake (Trent River). Surficial sediment concentration ranged up to 2 ppm PCBs, and typically varied between 0.5 and 1.5 ppm. Subsurface concentrations were generally higher than surface concentrations and ranged up to 2.4 ppm, though this pattern was not consistently observed at all sites.

Laboratory sediment bioassays showed that there were no acute or chronic effects on the test organisms (mayfly nymphs, midge larvae and fathead minnows) at those concentrations typically encountered in Otonabee River and Rice Lake sediments. The fathead minnows did show, however, that PCBs are biologically available from the sediments, since tissue levels of PCBs at the end of the 21-day tests were higher than sediment concentrations.

Young-of-the-year fish data and sport fish data both show that a number of fish species have elevated levels of PCBs in their tissues. Levels in young fish in the Otonabee River have fallen considerably from levels recorded in the early 1980's, with a lesser decline in Rice Lake. There appears to have been an overall decline in PCB residues in sport fish since the 1980's. However, levels in carp from Rice Lake remain relatively unchanged since 1984.

The mussel biomonitoring study found elevated levels of PCBs in mussels at the Rink St., Park St., and to a lesser extent, the Romaine St storm sewer discharges. The data indicate that PCBs are still being released to the system through these storm sewer systems. These sewers drain the two sites where historical use of PCB containing fluids has been documented.

The elevated levels of PCBs in mussel tissues indicate that source control measures currently pursued by the Ministry need to be continued. The extent of sediment contamination, coupled with the lack of acute or chronic effects on sediment-dwelling organisms suggests that it is impractical to consider sediment removal as a remedial measure. Progress towards effective source control could be monitored through mussel exposure studies conducted on a regular basis.

Since PCBs are biologically available from the sediment and appear to be contributing to tissue residues in young fish and sport fish, monitoring studies focused on the affected species need to be continued.

1.0 INTRODUCTION

In the mid-1970's, PCBs were detected in young fish from Rice Lake and the Otonabee River during routine sampling for the Ministry's Young-of-the-Year Fish monitoring program. Subsequent investigations of water, sediment and biota of the lake and river system by both provincial and federal agencies revealed that PCB contaminated sediments existed from the City of Peterborough down into Rice Lake. Biological testing found that PCBs were being accumulated in fish tissues and were linked to residues in sediments. The sources of the PCBs were identified as storm sewer discharges that drained from two industrial sites in Peterborough; the Canadian General Electric plant, which, among other products, manufactured electrical transformers, and; the Outboard Marine Corp (OMC) plant. Both sites had a history of PCB use, either in electrical transformers, or in the use of hydraulic fluids containing PCBs.

A number of studies have been undertaken of biota and sediments since the problem was initially identified. The current study summarizes data from the most recent investigations on sediment quality and fish tissue residue monitoring.

1.1 Sediment Assessment

Previous studies of the Otonabee River - Rice Lake system have identified a number of contaminants in sediments at levels above provincial guidelines. The presence of PCBs in sediments originating from sources in Peterborough has been well documented through studies conducted by MOE and Environment Canada (Maude *et al* 1992; Jaagumagi and Petro 1992; Mudroch 1993). Recently, the presence of PAH compounds in sediments has been identified in the Peterborough area, and has been linked to the historical operation of a coal gasification plant (Raven Beck 1993).

The studies undertaken to date indicate that PCB contamination of the sediments extends over a very broad area. Sediments are contaminated into the low ppm range throughout most of Rice Lake and elevated PCB levels extend down into the Trent River system as well. Mudroch (1993) found PCB concentrations in Rice Lake were typically below 1 ppm. Jaagumagi and Petro (1992) found similar results with a high of 1.4 ppm in Rice Lake sediments. Maude *et al* 1992, found higher levels concentrated at the mouth of the Otonabee River, where they noted levels of up to 15 ppm.

Many of these studies have documented the downstream extent of the contaminated sediments, particularly in Rice Lake, and additional characterization of these areas was not considered necessary. However, there is little current knowledge of the extent of contamination in the Otonabee River. The limited studies that have been done in the river have concentrated on the main river channel, where there is little accumulation of fine sediments. Extensive deposits of fine sediments exist along the banks of the river (in places up to 1m of fine sediments can be found overlying clay) which have not been sampled in the past.

Since organic compounds such as PCBs and PAH tend to partition to organic matter, areas of fine-grained sediment accumulation typically have higher concentrations of contaminants. Over the long term, such areas would serve as the main reservoirs for release of contaminants back into the system.

Additional characterization of sediment contamination in Little Lake was also considered necessary in order to compare current contaminant levels with those from previous studies. This type of information would provide a means of assessing whether sediment conditions were improving. The 1996 study was undertaken as a means to better define sediment conditions in the Otonabee River and to determine whether there is a need for remediation of the sediments, both within the river and Little Lake.

The Provincial Sediment Quality Guidelines identify a process for evaluation and management of contaminated sediment problems. The sediment assessment procedure outlined in the Provincial Sediment Quality Guidelines (Persaud *et al.* 1993) and presented in detail in Jaagumagi and Persaud (1996), requires that biological assessment be undertaken where there are exceedances of the Severe Effect Level and recommends such studies where levels exceed the Lowest Effect Level. The need for management action, including remediation, is not based on chemical criteria alone, but rather, upon the severity of biological effects determined as part of the biological assessment. The high concentrations of PCBs in the Otonabee River and

Rice Lake, and the presence of coal tar wastes that have been recorded in previous studies, would warrant additional biological investigation.

Biological tests are used to determine the risk level that organisms are exposed to as a result of the levels of sediment contamination. A component of this risk assessment is based upon toxicity to aquatic organisms, which is usually assessed through laboratory tests. In addition, congener-specific PCB analysis was also included (results are not included in this report), to assess the potential toxicity of the sediments. These types of tests are necessary in order to determine whether additional remedial actions are required. Since sediment quality guidelines have been developed on a generic basis for application throughout the province, they are not suitable for determining the need for cleanup on a site specific basis. Biological tests that measure the impact of contaminated sediments directly on aquatic organisms are usually the best means of assessing whether contaminants pose a problem to aquatic life and require remedial action.

1.2 Mussel Biomonitoring

Mussel biomonitoring studies in the Otonabee River/Rice Lake system have been conducted by MOE since 1985 and were reported in Maude *et al.* (1992) and in technical memoranda submitted to the Peterborough District Office. The earlier studies were undertaken to identify the sources of PCBs found in carp and young fish in the Otonabee River and Rice Lake. These studies found that the primary sources of PCBs were the Rink Street sewer and Park/Cameron Street sewer. Minor sources were the Romaine Street sewer and the sewage treatment plant (STP).

Later studies were undertaken to monitor the progress of the ongoing remedial activities. Between 1985 and 1993, the concentration of PCBs in mussels declined substantially. However, PCBs in mussels at the Rink Street and Park/Cameron sewer outfalls remained significantly higher than other sites in the river, which indicated that PCBs were still entering the river at these two sites.

The 1996 study was undertaken to monitor the continuing progress of remedial activities within the sewershed. As well, there was a need to determine if PAHs in sediments immediately upstream of Rink Street (Raven Beck 1993) were biologically available. Other studies have found that mussels unlike fish and other higher organisms bioaccumulate PAHs (Kauss *et al.* 1991) and hence are ideal organisms for monitoring this group of contaminants.

1.3 Sport Fish Contaminant Monitoring

As part of the Sport Fish Contaminant Monitoring Program, sport fish have been collected in the Otonabee River/Rice Lake system and analyzed for PCBs, organochlorine pesticides and mercury since 1977. Historically, sport fish have been collected from the Otonabee River upstream of Trent University, at Little lake, and at Bensfort Bridge (between Highway #7 and Rice Lake) and in Rice Lake off the mouth of the Otonabee River and at the east end. The resulting consumption advice from these studies has been published and regularly updated in the MOE/MNR publication "Guide to Eating Ontario Sport Fish".

Currently, there are no PCB-related sport fish consumption advisories in the Otonabee River upstream of Little Lake. Sport fish consumption advisories due to PCBs have been issued for carp in the Otonabee River below Highway #7 and throughout Rice Lake. Consumption advisories due to PCBs have also been issued for walleye below Highway #7, brown bullhead, largemouth bass and walleye at Rice Lake off the mouth of the Otonabee River.

1.4 Young-of-the-Year Fish Monitoring

Young-of-the-year fish serve as a valuable monitoring tool for the availability of contaminants, and possess certain advantages over older sport fish. Young fish tend to be more local in their movement and thus are typically confined to a relatively small area. In addition, they can serve as indicators of recent sources of contaminants, since the tissue residues in these fish can only have been accumulated for the short time period that has elapsed since hatching.

Since the discovery of elevated PCB residues in fish from Rice Lake in 1976, juvenile yellow perch *Perca flavescens* have been collected from the Otonabee River and Rice Lake to assess temporal and spatial trends in PCB contaminant availability. Perch are an integral part of the forage base for the sport fish industry. Juvenile perch also provide a link for contaminant transfer to higher trophic levels.

2.0 METHODS

2.1 Sediment Sampling

The sediment sampling component was designed as a three phased study. The first, or initial, phase was directed towards locating areas of fine sediment accumulation in Little Lake and the Otonabee River since organic compounds tend to bind preferentially to fine-grained (organic) sediments. From this initial survey, the location of sediment sampling stations was determined. The second phase consisted of collection of core samples, or Ponar grabs where cores could not be obtained, for chemical characterization of the sediments in order to determine the area and depth of contamination. The third phase consisted of biological assessment to determine the effects of elevated levels of sediment contaminants.

Phase I

An initial reconnaissance survey was conducted in June of 1996 to map fine sediment distribution in Little Lake. This involved collection of samples with grab and core samplers for visual inspection. A set of transect lines running from east to west were sampled at regular intervals in Little Lake, including areas downstream of the location of the former coal gasification plant. A Ponar sampler was used to determine surficial sediment type. A map of sediment types was produced from this information.

Locations of fine sediment accumulation in the Otonabee River were determined during a previous reconnaissance survey conducted in 1992. Locations sampled were based upon information from that survey.

Phase II

Immediately following the Phase I investigation, sediment samples were collected from selected sites in Little Lake and the Otonabee River (Figures 1 and 2). Cores could not be obtained from Little Lake due to the loose, unconsolidated material encountered and, consequently, samples collected from Little Lake were obtained using a Ponar grab sampler.

Cores were obtained for all locations in the Otonabee River. Cores were collected using a benthos gravity corer fitted with a 2.5 inch diameter plastic tube. The corer was forced into the sediment by hand until refusal (usually to the underlying clay layer). Cores obtained were sectioned into 10 cm sections rather than on the basis of visible discontinuities, since most of the sediment profile was homogeneous. At all stations 3 sections of 10 cm each were retained, though in some cases core lengths up to 50 cm were obtained. Three replicate cores were collected at each station, the corresponding sections were composited to formed single sample, and samples of the composite were submitted for PCB, PAH and TOC analysis. Based upon initial sample results, in Phase III, a selected number of samples (4) were submitted for congener specific analysis of PCBs in order to determine whether, and at what concentration, the more toxic congeners were present.

Phase III

Phase III was based upon the results of the chemical characterization undertaken in Phase II. In October 1996, sediment samples were collected at 4 locations (RS-1, OR-1, OR-6 and OR-7) for determination of toxicity potential and bioavailability to aquatic organisms, which were assessed through two biological tests.

The first test was included to assess availability of contaminants from the sediments to sediment-dwelling organisms. This consisted of tissue residue analysis of benthic organisms at up to 5 locations. The benthic organisms selected were sediment burrowing forms that were most likely to ingest and, as such, accumulate, sediment-bound contaminants. However, sufficient weight of organisms could not be collected for chemical analysis of tissues. As a result, tissue residues were measured in sediment bioassay organisms at the completion of the bioassay testing.

The second test was comprised of laboratory sediment bioassay tests at those sites where high contaminant concentrations were encountered. This would determine whether levels were having adverse effects (lethal or sublethal) as well as potential bioavailability of the compounds. Bioavailability was measured only in one test organism, the fathead minnows.

A follow-up study was conducted in July 1998. Selected locations were chosen for additional sediment sampling for congener-specific PCB analysis. The results from this component are not included in this report, but will be reported separately.

2.2 Laboratory Sediment Bioassays

Whole-sediment toxicity tests were conducted for four field locations in 1996, using the mayfly nymph, *Hexagenia limbata* (21-day exposure, survival and growth), the midge larvae, *Chironomus tentans* (10-day exposure, survival and growth) and the juvenile fathead minnow, *Pimephales promelas* (21-day exposure, survival and chemical bioaccumulation). The battery of sediment toxicity tests provides a number of endpoints using organisms representing different trophic levels in order to measure differences in sediment quality. The laboratory toxicity tests provide a cost-effective technique for determining if sediment-associated contaminants are harmful to benthic organisms or are being released into the water-column. In conjunction with appropriate negative and reference control sediments, spatial differences in sediment quality, the relative availability of contaminants and their potential impacts can be ascertained. Sediment contaminant concentrations were based on samples prepared for laboratory toxicity testing. The sediment was analysed for particle size, nutrients, metals, total PCBs, organochlorine pesticides and chlorinated benzenes. Surviving fathead minnows were submitted for tissue analysis of total PCBs.

2.2.1 Sample Collection and Site Description

In early October 1996, surficial sediment was collected at three locations along the Otonabee River (Stations OR-1, OR-6 and OR-7) and at one site in Little Lake near the Rink Street sewer (Station RS-1) (Figures 1 and 2).

Samples were collected with a 12" X 12" stainless-steel Ekman grab sampler. At each station, approximately 15 L of composited surficial sediment (top 5 to 10 cm) was collected from several grabs. The composited sediment was placed into 20 L plastic buckets lined with food-grade polyethylene bags and transported to the Toronto, Ontario laboratory where they were stored at 4°C until required.

Normally a reference control sediment is collected near the study area, along with the test sediments, in order to measure biological effects due to sediment type and low-level contamination. Unfortunately there was no suitable area available given the layout of the site. Sediment collected from Honey Harbour, Ontario served as a negative control. The negative control sediment is a relatively uncontaminated sediment that provides a measure of test acceptability (ASTM, 1997).

2.2.2 Analytical Methods

Chemical analysis of sediment and biota samples was carried out by the OMOE, Laboratory Services Branch, located in Toronto. Routine test methods are described in the *OMOE Handbook of Analytical Methods for Environmental Samples* (OMOE, 1983). Quality assurance procedures included method blanks, spikes, duplicates and standard reference materials.

Sediment Nutrients and Particle Size Characterization

Homogenized bulk sediment (<2 mm fraction) was measured for total phosphorus (TP), total Kjeldahl nitrogen (TKN) and percent weight loss on ignition (LOI) which measured approximate organic content. Sediment total organic carbon (TOC) was determined with a LECO carbon analyzer using a dry combustion technique which oxidized carbon to CO_2. Particle size was measured on 50 g, air-dried samples using a Microtrac particle size analyzer for the size range 1.0 mm to 0.1 µm. This was to provide data for %sand (2mm -62 µm), %silt (62- 3.7 µm) and %clay (3.7 - 0.1 µm) size classes. Detailed test methodology is described in OMOEE (1995a; 1995b).

Trace Metals in Sediment

Prepared sediment samples were digested using a concentrated aqua-regia acid mixture (1 part HNO_3 to 3 parts HCl). The dissolved trace metals including As, Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn in the digestates were detected by inductively coupled argon plasma atomic emission spectroscopy (ICP-AES), and Hg by flow injection vapour generated flameless atomic

absorption spectroscopy (AAS). Detailed test methodology is described in OMOEE (1994a).

Organic Chemicals in Sediment

Moist sediment samples were extracted with acetone and dichloromethane. The extract was transferred to a rotary evaporator, concentrated and fractionated on a Florisil column. Different solvent combinations were used to elute the extracts into three groups: fraction A1 contained total PCBs, five Aroclor groups, hexachlorobenzene, heptachlor, aldrin, octachlorostyrene, pp-DDE and mirex; fraction A2 contained a- & b-BHC, a- & b-chlordane, op-DDT, pp-DDD, pp-DDT; and fraction A3 included heptachlor epoxide, oxychlordane, dieldrin, endosulfan I & II, endosulfan sulphate, endrin and methoxyclor. Analytes were identified and quantified using capillary gas chromatography equipped with a Ni^{63} electron capture detector (GLC-ECD). Detailed test methodology is described in OMOEE (1994b).

Organic Chemicals and Percent Lipid in Biota

Pooled whole fish samples (~5 g) were thawed, homogenized and acid digested using concentrated hydrochloric acid (HCl) on duplicate samples per station. The digestate was reacted with a mixture of 25% dichloromethane in hexane. The extract was treated with sodium bicarbonate to ensure neutralization and dried with anhydrous sodium sulphate. Dichloromethane-cyclohexane was added to the evaporated samples, followed by clean-up and detected by capillary gas chromatography equipped with a mass selective detector. Final results are reported on a wet weight basis for 14 chlorinated organic compounds and 14 pesticides. Percent lipid was determined on an aliquot (25 mL) of the final extract obtained prior to clean-up. The solvent was allowed to evaporate by air-drying in a fumehood for 24 hours and lipid residues were measured. Detailed test methodology is described in OMOE (1990).

2.2.3 Laboratory Biological Testing Methods

Basic Experimental Design

Sediment biological tests were conducted according to OMOE standardized procedures (Bedard *et al.*, 1992) and are briefly described below. The bioassays were static, single-species tests using whole-sediment. The experimental unit was a 1.8 L test chamber containing prepared sediment and dechlorinated municipal tap water (1:4, v:v). The chambers were randomly placed into a holding tank at ambient room temperature and maintained under a 16:8 hour, light:dark photoperiod and continuous aeration. Moist field-collected bottom sediment was pressed through a 2-mm stainless-steel sieve to remove existing large biota and debris prior to use. Sieving was completed on October 21, 1996. Subsamples of this homogenized sediment were submitted for chemical and physical characterization according to standard OMOE procedures (OMOE, 1989). The sieved sediment was homogenized with a spatula and stored in 4 L acid-rinsed glass jars until required. Three hundred and twenty-five millilitre aliquots of homogenized sediment were placed into the test chamber and overlaid with the test water. After settling overnight, the chambers were aerated continuously until the termination of the test. A clean sediment collected from Honey Harbour, Georgian Bay was used as the negative control. Negative control mortality must not exceed 15% for mayflies and fathead minnows and 25% for chironomids or the test is declared invalid.

Water in the exposure chambers was regularly monitored for pH, conductivity, total ammonia, un-ionized ammonia and dissolved oxygen. Dead organisms were removed and the numbers recorded on a daily basis. Any signs of abnormal behaviour of the test organisms or changes in appearance of the test chambers were noted. Water loss due to evaporation was replenished as needed.

***Hexagenia limbata* Lethality and Growth Assay**

The toxicity test used four month old laboratory-reared mayfly nymphs with an average wet weight of 4.72 mg ± 0.40 (s.e.) (n=37). The nymphs were raised from eggs collected by Dr. J. Ciborowski at the University of Windsor, Windsor, Ontario. Mayflies were reared according to OMOE procedures (Bedard *et al.*, 1992) and methods described in the literature (Friesen, 1981).

The rearing procedure involved the transfer of 600 newly-hatched nymphs to a 6.5 L aquarium which contained 2 cm of autoclaved sediment and 5.6 L dechlorinated tap water. Animals were maintained at

ambient room temperature under a 16:8 hour, light:dark photoperiod with constant aeration and fed a vegetable diet.

Test organisms were retrieved from the rearing aquaria by sieving small portions of sediment in a 500-µm mesh brass sieve. The nymphs were washed into an enamelled tray which held a fine mesh sieve and aerated, dechlorinated water. A Pasteur pipette (5-mm opening) was used to transfer the mayflies into 100 mL beakers of water and the contents were gently poured into the test chambers. Each test involved adding ten nymphs for each of the four replicate test chambers for a period of 21 days. Animals were not fed during the length of the test.

At the end of the test, the contents of each test chamber were emptied and rinsed in a sieve bucket. Surviving animals were counted and transferred to 150 mL beakers holding 100 mL dechlorinated water. The nymphs were immobilized with Alka-Seltzer®, blotted dry and individuals weighed to the nearest 0.01 mg.

***Chironomus tentans* Lethality and Growth Assay**

Each toxicity test used 10-12 day old, cultured chironomid larvae weighing an average wet weight of less than 1 mg. The OMOE continuously cultures *C. tentans* larvae from egg to adult following standard methods (Bedard *et al.*, 1992, Mosher *et al.*, 1982, Townsend *et al.*, 1981). Egg masses were acquired from Dr. J. Giesy at Michigan State University, Lansing, Michigan and have been cultured for several generations in our laboratory.

Initially, the midges were reared in enamelled trays for a period of 10 to 12 days and then maintained in a 21 L aquarium containing 1.6 L of silica sand. The cultures were held at ambient room temperature with continuous aeration and under a 16:8 hour, light:dark photoperiod. The larvae were provided a vegetable diet *ad libitum*.

Second and third instar larvae were directly transferred from the enamelled rearing pans into the test chamber using the 5-mm opening of a Pasteur pipette. A total of 15 animals were added per chamber to each of the four replicates. Animals were fed a daily diet of 30 mg of a Cerophyll®:Tetra Conditioning Vegetable® (3:2, w:w).

After 10 days, the contents of the test chambers were emptied and washed in a sieve bucket. Surviving animals were sorted, removed and placed into 150 mL beakers holding 100 mL dechlorinated water and 15 mL silica sand. The larvae were counted, blotted dry and individuals weighed to the nearest 0.01 mg.

***Pimephales promelas* Lethality and Bioaccumulation Assay**

The tests used cultured, juvenile fathead minnows with an average wet weight of 312 mg ± 17 (s.e.) (n=30). The minnows were cultured at the OMOE laboratory and followed techniques which, for the most part, are US EPA procedures (USEPA, 1987) with minor revisions (Bedard *et al.*, 1992).

Cultures were maintained at 20°C in a flow-through dechlorinated water system and under a 16:8 hour, light:dark photoperiod. Breeders were kept in 60 L glass aquaria and eggs were laid on spawning tiles. The tiles were incubated in a 25°C water-bath and the developing larvae were transferred to 400 L fibreglass holding tanks. Larval fish were fed 48-hour old live brine shrimp while juveniles and breeders were provided frozen brine shrimp. Each size class was fed *ad libitum*.

Each test chamber received 10 juvenile minnows in triplicate per sample. The minnows were sorted into 250 mL glass beakers in groups of five. The contents of the beakers were emptied into a small net and the minnows released into the test chamber.

The minnows were exposed for 21 days and fed NutraFin Staple® diet in an amount equivalent to 1% of the average starting wet weight, on a daily basis. After 21 days the surviving fathead minnows were pooled from each replicate, counted, immobilized with Alka-Seltzer® and placed into 30 mL glass vials and frozen pending chemical analysis.

Reference Toxicant Testing

A water-only reference toxicity ($CuSO_4$) test was conducted with *H. limbata* and *C. tentans* for 48-hours and LC50s were calculated. The static tests consisted of four test concentrations and a control. The nominal copper concentrations were 0.05, 0.25, 0.5, 1.0 and 3.0 mg/L. Ten mayfly nymphs or midge larvae

were placed into each of four replicate 250 mL beakers. To help reduce stress, five glass tubes were placed into the mayfly test beakers and a fine layer of silica sand was added to the midge test containers. Water quality parameters were recorded at 0 and 48 hours. The mayfly test used five month old laboratory-reared mayfly nymphs with an average wet weight of 4.3 mg ± 0.3 (s.e.). The midge larvae were 10-12 day post-hatch with an average wet weight < 1 mg in each set of tests.

Bioassay Schedule for Otonabee River 1996 Sediment Samples

Test Organism	Species	Starting Date ('96)	Completion Date ('96)	Test Duration
Mayfly	*Hexagenia limbata*	October 23	November 13	21 days
Chironomid	*Chironomus tentans*	November 19	November 29	10 days
Minnow	*Pimephales promelas*	November 14	December 5	21 days

2.2.4 Statistical Methods

Statistical analyses were performed using the SAS® software package (SAS, 1985). Comparisons were made among the test and control sediments using One-Way Analysis of Variance (ANOVA) and Tukey's studentized range test (HSD) and planned comparisons (Steel and Torrie, 1960). Dunnett's one-tailed *t*-test was used solely to compare mortality between the control and test sediments and the associated minimum significant difference (MSD) was described as a measure of test sensitivity. Analysis was made on arc-sine transformed mortality data. Homogeneity of variance across groups was tested using Bartlett's test. Coefficients of variation (C.V. %) were calculated for each endpoint as a measure of test precision. Spearman rank correlation analysis was used to investigate the correlation among the different biological endpoints for each species and sediment characteristics. Simple linear regression was used to measure the strength of the relationship between tissue and sediment chemical concentrations. LC50's (including the associated 95% confidence limits) were calculated using software developed by Stephan (1977) and were estimated by probit analysis. All contaminant residues are converted to a dry weight basis using a dry weight ratio of 0.15.

2.3 Mussel Biomonitoring

Thirteen stations including eight long term sampling sites were monitored (Table 14, Figure 10). Mussels (*Elliptio complanata*) with a maximum shell length of 65 to 72 mm were collected from Balsam Lake on June 24, 1996 and maintained in Balsam Lake water with aeration at room temperature in 22 L buckets lined with food grade inserts. Concentrations of organochlorine contaminants in these mussels are usually below the analytical detection limits (Kauss and Hamdy 1985).

On June 25, 1996 mussels were transferred into envelope-shaped cages 30 cm by 45 cm of 1.25 cm galvanized mesh poultry netting. Two cages containing seven and eight mussels were placed on the substrate at each station.

On July 16, 1996 after an exposure period of 21 days, the mussels were collected. They were immediately shucked, wrapped individually in hexane-rinsed foil, stored on ice and shipped to the MOE Laboratory in Etobicoke, Ontario. Mussel tissue was stored at -20° C prior to analysis.

Three replicates from each station were analyzed for PCBs and organochlorine pesticides; one replicate was analyzed for PAHs. At stations where

PAHs exceeded the detection limit two additional replicates were analyzed. The results were statistically analyzed using a one-way ANOVA. If the ANOVA indicated a significant difference among stations ($P<0.05$), then a Tukey's Honestly Significant Difference (HSD) Test (Steel and Torrie 1960) was performed to identify homogeneous groups ($P<0.05$). Stations with all three replicates below the detection limit of 20 ng/g were considered in the same homogenous group. At stations where one or two replicates were below the detection limit, one-half of the detection limit was assigned for these values for the purposes of statistical analysis. In most cases, this would be an over estimate of the real value and therefore could result in a type II error (i.e. not declaring a significant difference where one occurred).

2.4 Sport Fish Contaminant Monitoring

Since MNR was unable to collect sport fish samples, staff of the Sport Fish Contaminant Monitoring Program of EMRB collected sport fish in 1996/1997 from the Otonabee River/Rice Lake/Trent River system.

Sport fish were sampled August and September 1996 at all of the historic locations listed previously except Rice Lake east which was sampled in June 1997. Sport fish were collected using a 12 foot Smith-Root electroshocking boat. Fish were weighed, measured and a skinless boneless dorsal fillet was removed, wrapped in hexane-rinsed foil, stored on ice and shipped to the MOE laboratory in Etobicoke, Ontario. Fish tissue was stored at -20° C prior to being analyzed for PCBs, organochlorine pesticides and mercury following standard Ministry protocols (OMOEE 1995). Since only PCBs are a concern in this study, the results of the other analyses will not be dealt with in the report.

Sport fish consumption advisories were calculated using standard methods outlined in The Guide to Eating Ontario Sport Fish (OMOE/OMNR 1997). For each species, the regression curve of length versus PCB concentration was calculated using the constrained non-linear power series regression curve algorithm in the Advanced Statistics package of SPSS (SPSS 1995). The curve was used to calculate the consumption advice (which will be incorporated into the next issue of the Guide) and the predicted contaminant concentration in a "standard-sized" fish. Contaminant concentration in a standard length fish is calculated to provide a valid means of comparing contaminant levels temporally and spatially.

2.5 Young-of-the-Year Fish Monitoring

Young-of-the-year yellow perch were collected at several sites in 1996: at 3 sites in the Otonabee River (downstream of the Rink St. sewer, at Beavermead Park, and below the STP (above Hwy 7)), in Rice Lake (south shore of Spook Island), and in Seymour Lake, downstream of Rice Lake (Figure 14). Fish length ranged between 56-70 mm, with the exception of the site below the STP (mean length 100±5 mm).

Spottail shiners were collected in the Otonabee River above Little Lake near the current location of the Canadian Tire store on the west bank (no perch available). Spottails were also collected at the Rink Street sampling site, in Rice Lake (Spook Island) and downstream of Rice Lake (Seymour Lake) for comparison.

Fish were netted using a 60-foot seine net with a 2 metre bag and 0.6 mm mesh size. Captured fish were immediately placed in hexane rinsed aluminum foil pouches and kept cool until they could be processed (less than 30 minutes). Individual perch were combined into composite samples (2-5 fish per composite) and composite sample size varied from site to site ($n = 2$ to 5). Fish from each site were measured for total length (head to compressed tail), wrapped in hexane rinsed aluminum foil, placed in plastic bags, labeled with collection site name, sampling date, species collected, and composite number. Samples from each site were tied together, frozen on dry ice and kept frozen at -20°C. Fish were removed from freezers, homogenized and analyzed at the MOE laboratory in Etobicoke in accordance with lab protocols.

3.0 RESULTS

3.1 Sediment Sampling

The locations of all sampling sites are provided in Table 1 and are shown on Figures 1 and 2.

At each site, sediment was visually inspected and sediment type was noted (including any odour, visible discolorations, etc) and this information is also included in Table 1.

Physical Characteristics

Sediment physical characteristics noted in this section are based on visual observations made during Phase I sampling. Characterization of particle sizes was not undertaken, except on bioassay sediments.

Substrate upstream of Little Lake in the Otonabee River consisted mainly of rock. Embayments along the west shore yielded only a thin layer of fine sediment overlying rock and suggests that any fine sediment that accumulates in these areas will be temporary. As a result, sediment samples could not be obtained in this area.

Sediment type in Little Lake varied from gravel and rock in the central part of the lake adjacent to the Otonabee River inflow, to fine, loose silty material in the north west and southwest sections of the lake. It appears that flow from the Otonabee River scours the central part of the lake with fine sediment accumulation in more quiescent areas in the north west and southwest parts. Sediments in the southeast section of the lake were a mix of sand and gravel, and this pattern suggests that flow from the Otonabee River is directed south and then back west at the eastern edge, creating a large backflow. The existence of a backeddy would account for fine sediments being confined to the southwest section. A similar backflow effect does not appear to be present along the north side, and fine sediment accumulations were found from the mouth of the Otonabee River over to near the Trent Canal. However, the shoreline configuration of the north side differs from the south side, where a large bay exists due to the point of land. Sediment type graded to mainly sand and gravel at the eastern end of Little Lake adjacent to Beavermead Park.

Sediment type in the Otonabee River downstream of Little Lake was characterized by rock and/or gravel in the center of the channel. However, extensive deposits of fine-grained silty sediments were found along the banks of the river, particularly in protected areas. In most areas, cores of 30cm and more were obtained, and in many of these locations there was significant compression of the material in the core, suggesting a high water content. This in turn suggests that the material is loosely packed and could be relatively easily eroded. Details of sediment type at individual sampling locations are provided in Table 1.

Sediment PCBs

PCB levels in Little Lake surficial sediments (not including the area near the Rink Street sewer outfall) were below 1ppm at all sites (sediment PCB concentrations in Little Lake and the Otonabee River are shown in Table 2). Concentrations were highest at the upstream end (west side) of the lake (960 ppb at station T1-1). Little or no deposition was found to occur in the central portion of the lake, since substrates here were primarily rock and gravel. This area is likely subject to considerable scour from the river, which empties into the lake from the west at approximately its mid-point. The strong flow from the Otonabee River would preclude accumulation of fine-grained material in this section.

Sampling for PCBs was focused on the fine-grained sediments that have accumulated on either side of the main scour channel along both the north and south sides of the lake. Along the south side, the highest concentrations of sediment PCBs were towards the western end. Data from other studies (Maude *et al* 1992) indicate that this area could have received inputs from the Romaine St sewer. Caged mussel studies (Section 3.3) indicate intermittent discharges of PCBs have occurred by means of the sewer.

Since PCBs and other hydrophobic organic compounds typically bind to organic particles, these compounds are usually found in higher concentrations in areas of fine-sediment accumulation. The higher levels of PCBs in sediments near the western end of Little Lake confirm visual inspection of the sediments that indicate a greater accumulation of fine-grained sediments in this section. The eastern end is characterized by hard (rock) substrates or sand, with little deposition of fine grained sediments. These areas would be expected to yield lower concentrations of PCBs.

The presence of fine grained sediment deposits along the northern shore demonstrate that this is a depositional area and elevated levels of PCBs were also obtained at these locations. Though both stations along transect T4 were in areas of fine-grained

sediments, the western end, closer to the upstream end of the lake, had higher concentrations (860 ppb) than the eastern end (400 ppb).

Two stations were located near the eastern shore of Little Lake, directly across from the inflow of the Otonabee River. Both stations were characterized by high sand content, with the substrate at station T3-2 nearly entirely comprised of sand. Sediment PCB concentrations were very low at both stations (180 ppb at station T3-1 and <D.L. at T3-2).

Comparison of levels in 1996 with results of the 1992 sampling conducted by Mudroch (1993) indicates there has been little or no decrease in sediment concentrations in Little Lake (Figure 3).

PCB concentrations near the Rink St sewer were 1.3 ppm (Table 2). This area during previous surveys has shown highly variable levels, that have ranged up to a high of 39 ppm.

Stations in the Otonabee River were all located along the sides of the channel in areas of fine sediment accumulation. Locations were chosen on the basis of physical factors favourable to sediment deposition, such as large back-eddies or bays. A number of large shallow bays exist at numerous points along the river from Peterborough to Rice Lake. In many cases a shelf of fine grained sediments was encountered at the margin of the river at the mouth of these bays, and these areas were chosen preferentially since resuspension of sediment from upstream areas would most likely be deposited in these areas.

Results of this study component (Table 2) show PCB accumulation to be highly variable, and no clear gradient was established with distance downstream (Figures 4 and 5). In the majority of the samples, surficial sediment concentrations of PCB were lower than subsurface layers, with the highest concentrations (up to 2400 ppb) usually in the 10-20 cm section. In only a few cases were there detectable levels in the 20-30 cm sections (these on occasion penetrated the clay layer). At only one station, OR-3, were concentrations in the 20-30cm section higher than in the 0-10 cm section. As noted in Table 1, the clay layer was not encountered at this location.

Overall, the highest PCB concentration encountered in the surficial (0-10 cm) layer was 1300 ng/g or 1.3 ppm at station OR-7 (Table 2, Figure 4 and 5). The highest subsurface concentration of 2400 ng/g or 2.4 ppm was in the 10-20 cm layer at station OR-2 though levels in the 10-20 cm section at station OR-3 were very similar (2300 ppb). Both the surface and subsurface concentrations noted above are higher than recorded in sediments of the Otonabee River during previous surveys (e.g., Jaagumagi and Petro 1991) and are typically in the range of concentrations encountered in Rice Lake. Sediment PCB concentrations did not exceed the Severe Effect Level of the Provincial Sediment Quality Guidelines (PSQGs) at any of the stations sampled, though concentrations at most stations exceeded the Lowest Effect Level.

Results of the congener-specific PCB analysis were not available for inclusion in this report and these results will be reported separately.

Sediment PAH

The results of PAH analysis are presented in Table 3. Since previous studies (Jaagumagi and Petro 1992) indicated that PAH contamination was more localized than PCB contamination, analysis was only undertaken for sites in Little Lake and for a short distance downstream in the Otonabee River (Station OR-1).

PAH concentrations were highest at RS-1 located near the Rink Street storm sewer discharge. Levels were 165.5 ppm total PAH, which was considerably higher than the LEL of 4 ppm, though still well below the SEL of 650 ppm (for a sediment of 6.5 % TOC).

Most sites in Little Lake were elevated relative to the PSQGs (LEL) with the highest concentrations at stations T1-1 and T4-2. Both stations were in areas of fine sediment accumulation. Concentrations were lowest in the sandy sediments at station T3-2. Concentrations ranged up to a high of 12.5 ppm at T1-1, which was located closest to the inflow of the Otonabee River.

3.2 Laboratory Sediment Bioassays

3.2.1 Water Quality Test Parameters

Conductivity, pH, total ammonia, un-ionized

ammonia and dissolved oxygen parameters were periodically measured on the overlying water for each test species and are summarized in Table 4. Values are reported as mean ± standard deviation.

Similar pH water quality measurements were recorded among the test sites, regardless of test species or study, and ranged from 7.6 to 8.1. Conductivity readings, for the test sediments, averaged 388 umho/cm, 398 umho/cm and 429 umho/cm in the mayfly, midge and minnow tests, respectively. Conductivity was consistently higher in the station RS-1 exposures and lowest in the negative control exposures. Dissolved oxygen within the test jars remained above the minimum acceptable level (>4 mg/l) throughout the test (OMOEE, 1994c). Test temperature averaged 18°C for the mayfly test and 21°C for the midge and minnow bioassays.

The amount of total ammonia present in the overlying test water and the succeeding un-ionized ammonia readings, based on test temperature and pH, are provided. Each of the test sediments resulted in un-ionized ammonia above the PWQO of 0.02 mg NH_3/L, in all three toxicity tests. Average values were lowest in the mayfly test (0.06 mg NH_3/L), increased in the midge test (0.11 mg NH_3/L) and were highest in the minnow test (0.20 mg NH_3/L). Among the test sediments, station RS-1 sediment yielded the highest ammonia levels (Range: 0.12 to 0.27 mg NH_3/L). The determining factor for the elevated ammonia does not appear to be related to either the test organism, or to the amount of TKN measured in the sediment but, rather, to slight differences in pH.

3.2.2 Sediment Characterization

The following sections summarize the sediment physical and chemical parameters to aid in the interpretation of the biological toxicity results. Chemical analysis is based on the sediment prepared for toxicity testing and results may differ from those reported for any field samples collected concurrently. Any dissimilarities are likely a reflection of *in-situ* chemical heterogeneity and/or sampling depth and sample handling.

Physical and Nutrient Properties

Sediments were characterized for % sand (2mm-62μm), % silt (62-3.7μm), % clay (3.7-0.1μm), % loss on ignition (%LOI), total organic carbon (TOC), total phosphorus (TP) and total Kjeldahl nitrogen (TKN) (Table 5).

The test sediments represented a gradation of loam substrates (Millar *et al.*, 1965). The most fine-textured sediment was collected from stations OR-1 and OR-7 and classified as a silt loam, followed by station OR-6 (loam) and station RS-1 was coarsest (sandy loam). The most nutrient-enriched test sediment was station OR-1, where the TOC (130 mg/g) surpassed the PSQG-SEL concentration of 100 mg/g. In addition, the TKN concentration was almost twice the SEL concentration. The remaining test sediments shared similar moderate amounts of TOC and TKN. Detrital material was found in each of the test sediments during initial sieving in the laboratory and included weeds, twigs, pieces of bark and other forms of aquatic vegetation. The negative control sediment was unlike any of the test sediments in terms of physical and nutrient properties and is representative of nearshore harbour sediment subjected to limited nutrient enrichment and sediment deposition.

Trace Metal Sediment Concentrations

Bulk sediment samples were analysed for 11 trace metals (Table 6). The sediment metal concentrations were compared to Severe Effect Level (SEL) and Lowest Effect Level (LEL) concentrations as outlined in the Provincial Sediment Quality Guidelines (PSQGs) (Persaud *et al.*, 1992). The SEL is defined as that chemical concentration in the sediment that could be detrimental to the majority of the macrobenthos and the LEL is the sediment contaminant concentration which can be tolerated by most benthic species.

None of the trace metal sediment concentrations were found above the PSQG-SEL concentration. Only Cu approached the SEL concentration of 110 μg/g at station OR-1 (78 μg/g) and station RS-1 (84 μg/g). These two sediments also had the highest As, Cd, Cr, Hg, Pb and Zn sediment concentrations but were near LEL concentrations.

Organic Chemical Sediment Concentrations

Concentrations of 19 organochlorine pesticides and 13 chlorinated organic compounds in the Otonabee River test sediments were below the

respective detection limits (Table 7). A trace amount of g-BHC (3 ng/g) was reported for station RS-1.

All test sediments contained measurable amounts of total PCBs (Table 7). At three sites the sediment PCB concentrations were above the LEL but below the SEL (after correction for TOC). Sediments with the highest PCB sediment concentrations (1,200 and 1,400 ng/g) also had an oily odour. These values were 44-times and 17-times lower than their respective SEL concentration.

Individual and total PAH sediment concentrations varied considerably among sites (Table 8). The highest PAH concentration was reported for station RS-1 (94.8 µg/g), an intermediate concentration for station OR-1 (11.8 µg/g), while several PAH compounds were found at trace or non-detect concentrations for stations OR-6 and OR-7.

At station RS-1, fluoranthene (20%), phenanthrene (15%) and pyrene (14%) were the main contributors, measured as a percentage of the total PAH, to a sum total of 49%. In comparison, no single PAH compound comprised >14% of the total PAH sediment concentration, in the other test sediments. The key PAH compounds measured in station RS-1 sediment are characteristic of coke and coal tar contamination, as observed at other Ontario sites (Jaagumagi and Bedard, 1996; Bedard and Petro, 1997).

3.3.3 Mayfly (*Hexagenia limbata*) 21-day Lethality and Growth Results

The biological data for the two endpoints, mortality and growth, is summarized in Table 9. Mortality in the negative control sediment was 5%, which was higher than any of the test sediments (0% - 2% mortality), but was not statistically significant (ANOVA; $p<0.57$). Among the test sediments, mayfly growth was significantly lower at station RS-1 (ANOVA; $p<0.0001$). Despite the fact there was a 35% growth reduction observed at station RS-1, the body weight still represented a reasonable level of growth, relative to the starting size of 4.7 mg and the negative control weight of 5.5 mg. In other words, station OR-1, OR-6 and OR-7 sediments promoted exceptional nymphal growth. The fairly low rate of growth observed in the negative control sediment was attributed to the longer storage time (~12 months) versus the freshly collected test sediments (~2 weeks). Mayfly growth depended on the quality and quantity of detrital material found in the sediment, since supplemental feeding was not provided throughout the test.

3.3.4 Chironomid (*Chironomus tentans*) 10-day Lethality and Growth Results

Results for chironomid growth and lethality are reported in Table 9. No significant differences in midge mortality were found among the test and control sediments (ANOVA; $p<0.11$). Percent mortality ranged from 0% to 15% and was well below the maximum acceptable criterion of 25% mortality. Each test sediment received a similar ranking using Tukey's multiple range test. Midge growth among the test sediments (14.7 mg to 16.7 mg) did not vary appreciably among sites or relative to the negative control weight of 16.0 mg (ANOVA; $p<0.06$).

3.2.5 Fathead Minnow (*Pimephales promelas*) 21-day Lethality Results

Juvenile fathead minnow percent mortality data is reported in Table 9. Control survival was 100%, along with the station OR-1 and OR-6 exposures. Minnow mortality at the other test locations (3%-10% mortality) was not statistically different from controls (ANOVA; $p<0.24$). A rough estimate of fish weight was made on pooled samples on Day-21. The final fresh weights did not differ >10% between test and control animals, suggesting all fish were feeding normally. During the test, it was observed that there was a lack of sediment disturbance and resuspension for RS-1 exposures by Day-11 which may either be evidence of sediment avoidance behaviour or due to the high sand content of the sediment which would limit burrowing activity. Given the similarity in fish weights among sites, it is expected that the low turbidity was due to sediment type.

3.2.6 Quality Assurance Data

An evaluation was made on the biological data in order to determine the repeatability of the test results (Table 9). Test precision, calculated as coefficient of variation or % C.V,. was very poor for the lethality endpoint, for each test organism (Range: 69% to 200%

C.V.). This coincides with the lack of any lethal effect measured among sites e.g. sediments are non-toxic. The low degree of toxicity observed at all sites is also reflected in the poor discriminatory power values (D.P.: 1 to 3). At the same time, the range in response was very similar, as shown by the minimum significant difference or MSD values of 9% to 25%. In other words, the test design was adequate in determining even small differences in mortality as being significant and met the same quantitative standards found in other sediment toxicity tests (Becker *et al.*, 1995; Burton *et al.*, 1996).

Both sublethal data sets had excellent coefficient of variation (Range: 7% and 8% C.V.) but generally had low discriminatory power. The *Hexagenia* growth endpoint provided only a slightly improved discriminatory capability (D.P. 5) due to the significant difference that was detected at one location. In general, each test organism and test endpoint was equally unresponsive in measuring an effect and is likely attributed to the uniformity in the types of sediment being tested.

The 48-hour copper LC50 (95% C.I.) for the water-only reference toxicant exposure for *H. limbata* was 0.69 (0.37 - 1.55) mg/L. This value was within the acceptable 48-h LC50 (± 2 s.d.) range of 1.31 (1.33) mg/L, according to a previous series of reference toxicant tests. Similarly, for *C. tentans*, the LC50 was 0.60 (0.49 - 0.72) mg/L, as compared to an expected 48-h LC50 (± 2 s.d.) of 1.34 (0.92) mg/L. This indicates that the relative sensitivity of the test organisms fell within a normal response range.

3.2.7 Chemical Bioaccumulation in *Pimephales promelas*

The examination of chemical availability to aquatic organisms is valuable for assessing the potential for chemical transfer through the food web. The primary objective of this test design is to make general observations on whole organism tissue concentrations as they relate to overall bulk chemical concentrations in the sediment and differences in chemical uptake among sites. Surviving fathead minnows were submitted for the analysis of total PCBs. All values are based on whole-body tissue concentrations. Values are provided as wet weight and converted using a dry to wet ratio of 0.15 in the calculation of biota-sediment accumulation factors or BSAFs.

The sources of organic compound accumulation to forage fish in the laboratory include direct contact with the sediment and uptake from the overlying water. Factors that control chemical accumulation by forage fish include those that affect chemical adsorption and desorption such as sediment organic content, particle size distribution and the chemical's solubility properties commonly expressed by the octanol-water partition coefficient, K_{ow} (Lake *et al.*, 1990). Biotic factors affecting uptake include metabolism and lipid content (Boese *et al.*, 1995).

Table 10 reports the total PCB tissue concentrations (wet weight) for each replicate and as an average value ± standard deviation for each station. In addition, the corresponding sediment PCB concentration (dry weight) is reported. Measurable amounts of PCBs were detected in fathead minnows for each of the test sediments. The highest PCB tissue concentration occurred at RS-1 (540 ng/g), followed by station OR-1 (490 ng/g). Substantially lower PCB tissue concentrations were reported at station OR-6 (100 ng/g) and station OR-7 (80 ng/g) and were near trace amounts. Total PCBs were at non-detect concentrations in the control fish (20 ng/g).

Concentration factors were calculated to assess the relative availability of total PCBs for the test sediments. The biota-sediment accumulation factor (BSAF) is defined as the ratio of organic chemical concentration in the fathead minnow, normalized for percent lipid, to that in the bulk sediment after correction for organic content (Lake *et al.*, 1990, Ankley *et al.*, 1992). Each individual replicate that was analysed consisted of approximately 15 individual animals.

$$BSAF = (C_t / L) / (C_s / TOC)$$

where,

C_t = tissue PCB concentration (ng/g tissue, dry weight)

L = tissue lipid concentration (%)

C_s = sediment PCB concentration (ng/g sediment, dry weight)

TOC = total organic carbon content of sediment (%)

BSAFs > 1.0, indicating that the concentration of a chemical found in the organism surpassed those

levels found in the bulk sediment, were reported at each test location. Substantial PCB accumulation was noted at the three Otonabee River and single Little Lake sites. Minnow PCB concentrations were 8-times to 29-times greater than the PCB concentration measured in the sediment (after correction for TOC) in the 21-day laboratory tests. Fish data were based on unpurged animals and any sediment found in the gut would have been included in the whole-body tissue concentration. However, in order for the gut content to account for the entire tissue concentration, over 100% of fish weight would need to be comprised solely of gut material. Obviously, the greatest proportion of the reported tissue concentration is due to chemical accumulation within other fish tissues. Boese *et al.*, (1996) concluded that BSAFs corrected for gut content were not grossly different than lipid-corrected BSAFs and the former approach is a valid measure of bioaccumulation potential.

The average lipid content of surviving minnows was 1.5% ± 0.4 (s.d.; n=10). The determination of percent lipid in biota can vary depending on the analytical method (Randall *et al.*, 1991). Therefore, the lipid content used in calculating the BSAF may be rather small and BSAFs were re-calculated using an average lipid content of 5%, which is commonly cited in the literature for juvenile fathead minnows (Nebeker *et al.*, 1989; McCarty *et al.*, 1992; van Wezel *et al.*, 1995). Even the more conservative BSAFs indicated a substantial degree of PCB availability at most test sites (Range: 2.3 to 7.0). An important unknown, however, is the degree to which PCB is available under reference conditions e.g. background PCB sediment concentrations, along with the associated final PCB tissue concentration, and whether this level differs from those found at some of the test sites.

There was a direct relationship between levels of total PCBs in fish and those measured in the test sediment. A progressive increase in sediment PCB concentration resulted in a similar level of increase in the fathead minnow. This positive correlation applied to both bulk PCB concentrations and TOC corrected PCB sediment concentrations ($p=0.00001$; $R^2=1$; $n=4$).

3.3 Mussel Biomonitoring

Mussels were recovered from all 13 stations. Mortality was low (Table 14). One cage was lost at station 12, however, there was enough mussel tissue in the remaining cage to complete the chemical analysis.

PAHs were below the detection limit at all stations. Therefore there was no need to analyze additional replicates and no statistical interpretation was required.

PCBs were detected in mussels at 7 of the 13 stations. A one-way ANOVA indicated that there was a significant difference among stations. Tukey's HSD test divided the stations into 4 homogeneous groups (Table 15). Stations within a homogeneous group are not significantly different from one another but are significantly different from stations in other homogeneous groups.

The first homogeneous group consisted of the stations upstream of the Rinks St. sewer outfall (with the exception of station 3), station 9 in Little Lake and station 10, upstream of the STP. The concentration of PCBs in mussels at these stations was less than the detection limit of 20 ng/g.

The second homogeneous group consisted of station 3 (upstream of Rink St. sewer outfall), station 8 (Romaine Street sewer outfall), Station 13 (downstream of Park Cameron sewer outfall) and station 11 (below STP).

The third homogeneous group consisted of the two stations (stations 6 and 7) at the Rink St sewer outfall. The last group consisted of one station (station 12) at the Park/Cameron sewer outfall.

3.4 Sport Fish Contaminant Monitoring

Eleven species of sport fish were collected in the Otonabee River/Rice Lake system (Table 16). Selected individual fish or composite samples of the five largest individuals were analyzed for PCBs (Table 17). The selection criteria were based on historical information from the area and species-specific affinity to accumulate PCBs. Generally, fish with a high fat content, such as carp, trout and other salmonids and bullhead tend to accumulate PCBs. Species such as bass, perch, pike and walleye tend not to accumulate PCBs unless there are very high concentrations in the

environment.

The summarized sport fish data are shown in Table 17. These include the values for the composite samples, as well as the mean, standardized-length mean, and range of PCB concentrations for each of the species at each location. Species not included in the table were not analyzed for PCBs.

3.5 Young-of-the-Year Fish Monitoring

All data collected from 1977 to 1996 are summarized in Table 18. Figure 14 provides a summary of PCB residues in young-of-the-year yellow perch from key sites in the Otonabee River, Rice Lake and Seymour Lake from 1977 to 1996. At all sites sampled, PCB concentrations in yellow perch were lower in 1996 than in any previous year.

4.0 DISCUSSION

4.1 Sediment Contaminant Analysis

Sediment PCBs

Concentrations of PCBs in Little Lake and Otonabee River surficial sediments were generally below 1 ppm, with the exception of a few sites. Concentrations were similar in Little Lake and the Otonabee River and suggest that PCBs have likely been transported downstream during resuspension of contaminated sediments. The variable concentration of PCBs with distance downstream suggests that deposition of this material has not been even and likely depends on the presence locally of physical characteristics that favour sediment deposition.

Previous studies have found that sediment concentrations of PCBs were highest adjacent to the Rink St sewer outfall. Maude *et al* (1992) found levels up to 24 ppm in these sediments while Mudroch (1993) found concentrations of 39 ppm. Both these levels were above the Severe Effect Level for PCBs. The higher concentrations recorded in Little Lake in these studies have been attributed to the Rink St sewer. Concentrations adjacent to the Rink St sewer during this survey, at 1300 ng/g (ppb), were considerably lower than levels encountered during previous studies. This could be due to a number of factors, such as reductions in PCB discharge, increased sediment disturbance or erosion in this area, or simply variability in sediment concentrations within this area.

Stations T1-1 and T2-1 were located below the Rink St sewer but above the Romaine St sewer. However, given the probable circulation pattern of the lake (i.e., clockwise in the part south of the Otonabee River inflow, and counter-clockwise in the northern part), these stations are likely within the zone of influence of both the Rink St and Romaine St sewers. The relatively high concentration of total PCB at station T1-1 as compared to other stations in Little Lake, and its proximity to the Romaine St sewer, suggest possible additional input from this source.

Stations on the north side of the lake (T4-1 and T4-2) would be primarily influenced by upstream sources in the Otonabee River such as the Rink St sewer. The likelihood of discharges from the Romaine St sewer influencing sediment concentrations in this part of Little Lake is very low and levels here would be mainly due to discharges or losses from the Rink St sewer. PCB concentrations were highest at locations closest to the inflow of the Otonabee River. While concentrations appear to decrease towards the east side, this area is also more heavily scoured by the current, given the hard and/or sandy substrate in this area.

Concentrations in Little Lake sediments were similar to those obtained during previous studies (Maude *et al.* 1992 ; Mudroch 1993) and were below 1 ppm at all locations. Mudroch (1993) obtained one core from Little Lake, which shows an increase in sediment concentrations from 0.87 ppm in the top 5 cm to 3.6 ppm at a depth of 27 cm, (the maximum length obtained). Maude *et al* (1992) in a core sample collected in Little Lake in 1985, found surficial layers had concentrations of approx. 5 ppm, while subsurface layers (between 5 and 10 cm) had concentrations ranging up to 15-20 ppm. Maude *et al* (1992) also noted that sediment concentrations were higher (1-5 ppm) near the Romaine St. sewer outfall. In this study, concentrations near the Romaine St. outfall were below 1 ppm (0.96 ppm). These differences are likely an artifact of what is probably an uneven distribution of PCBs in sediments, and should not be interpreted as a significant improvement without more detailed investigation. However, given the highly dynamic nature of this area, it is possible that sediments in Little

Lake have been resuspended and moved downstream over time. This could account for the lower sediment concentrations encountered in the 1996 study.

In the Otonabee River stations, sediment PCB concentrations obtained during this survey were somewhat higher when compared to results from other surveys. However, a review of past surveys indicates that in those cases sediments were collected from the main channel, and that areas of deposition along the edges of the channel, particularly where large wetland areas occur, have not been sampled in the past.

Core sampling results showed that concentrations in surficial sediments at stations immediately downstream of Little Lake were generally lower than in subsurface sections. Surficial PCB concentrations at stations OR-2, OR-3, OR-4 and OR-6 were less than half of the levels encountered in the 10-20 cm section. The distribution with depth clearly suggests that losses and deposition to the river have been higher in the past. However, this is offset slightly by station OR-1, where the highest levels were encountered in the top 10 cm.

The higher concentrations in surface sediments at station OR-1 suggest that there is continued deposition of PCB contaminated sediment in this section. Since Little Lake has been identified as, at the least, a temporary reservoir of PCB contaminated sediment, it would suggest that sediment continues to be washed down from Little Lake and deposited in quiescent areas downstream. (Maude *et al* (1992) noted that concentrations of PCBs in suspended sediment in Little Lake were above the LEL). Station OR-1 was located in the first major depositional area downstream of Little Lake (significant areas of sediment accumulation upstream of this site could not be located).

An increase in the levels of PCB in surficial sediment was noted at station OR-7. It is also noteworthy that surficial concentrations at this location were higher than at any of the upstream stations, and were also higher than levels encountered in Little Lake.

Levels in surficial sediments decrease downstream of station OR-7, suggesting that resuspension and deposition of material from upstream areas is not the major contributor to the higher levels at station OR-7. Other sources, including a historical landfill site in this area may warrant consideration.

Downstream locations yielded sediment concentrations of generally less than 1 ppm, and only at station OR-9 were surficial levels higher than subsurface levels. Subsurface sediment differed at station OR-9, in that there was a higher amount of fibrous (plant root) material and may suggest that this area has, in the past, been relatively more dynamic than the other areas sampled along the river.

Station OR-10, located in Rice Lake at the mouth of the Otonabee River had levels of less than 1 ppm. In contrast, Maude *et al* (1992) reported up to 15 ppm in sediments, though it is not clear from their data where at the mouth these samples were collected.

Past studies of Rice Lake have found sediment concentrations ranging up into the low ppm range (1-3 ppm at most sites)(Figure 9). The levels encountered in the Otonabee River were consistent with the levels in Rice Lake.

The current study, as well as past studies, indicate that, aside from the area directly adjacent to the Rink St sewer, PCBs are relatively evenly distributed within the Otonabee River- Rice Lake system. No identifiable areas of significantly higher concentrations, or "hotspots" could be located.

Coupled with the data from earlier surveys of Rice Lake, the current study suggests that there is both downstream transport of contaminated sediments in the river, with subsequent dispersion and deposition in Rice Lake, as well as deposition in quiescent areas along the banks of the river and in adjoining wetland areas. These areas, during high water, may also be susceptible to erosion of sediments, with subsequent re-deposition downstream.

Distribution with depth suggests that at most locations, deposition has been higher in the past, as evidenced by the higher concentrations in the middle (10-20 cm) sections. This, in turn, suggests that losses of PCB contaminated materials have been higher in the past. At a few locations, concentrations were also high in the bottom (20-30 cm) sections.

Since PCBs partition strongly to sediment organic matter, their availability is often best expressed as a function of the sediment organic carbon content.

Figure 6 shows the distribution of PCB compounds relative to sediment organic carbon content. As can be seen from the graph, while bulk values varied considerably among stations (Figure 4) when these are expressed on an organic carbon basis, concentrations throughout the river are relatively even. This suggests that availability of PCBs would vary only slightly among different locations.

Comparison of sediment PCB concentrations with other areas of PCB contamination suggests that levels in the Otonabee River-Rice Lake system are relatively low. Sediment concentrations at Wheatley Harbour, which has been identified as an Area of Concern (AOC), were typically in the range of 200-300 ppb and ranged up to approx. 650 ppb (Wheatley Harbour Stage 1 RAP Report). The primary effects identified at this site have been bioaccumulation and transmittal of PCBs through the food chain. In contrast, concentrations at Pottersburg Creek, which was the site of a PCB cleanup operation in the mid-1980's, ranged up to approximately 200 ppm at some locations (Canviro 1986). PCB levels in Hudson River sediments, below the GE plants located at Hudson Falls and Fort Edward, have been found to exceed 2,000 ppm (State of New York *et al* 1997). PCB levels in sediments of Waukegan Harbor (an AOC in Lake Michigan) near the Outboard Marine Corp. plant reached a high of 12,200 ppm. Some removal of contaminated sediments has occurred at this site (EPA 1997).

Sediment PAH

PAH concentrations were highest in Little Lake and may reflect the historical release of coal tar products from the coal gasification plant located on the Otonabee River just upstream of Little Lake. A number of sampling locations below the old gas plant were attempted, but no areas of sediment deposition were found, suggesting that deposition of any coal tar residues will only occur downstream, most likely in Little Lake.

Since coal tar wastes are highly viscous, they are unlikely to be dispersed over as great an area as PCBs. Despite the higher concentrations in areas of Little Lake where fine sediments have accumulated, levels throughout the study area were generally relatively low. In many urban areas, much higher concentrations are often encountered as a result of street runoff (storm sewer discharges). For example, levels in sediments along the Toronto Waterfront (Jaagumagi *et al.* 1991) ranged from 52 to 93 ppm near storm sewer discharges.

Raven Beck Environmental(1993) found high levels of PAH compounds in sediments adjacent to the former coal gas plant site (105,450 ppm), while in samples collected in embayments downstream of the site levels were very low, and were generally less than 2 ppm (the PSQG Lowest Effect Level for total PAH is 4 ppm). The higher concentrations in Little Lake obtained in this study suggest that material eroded from the Otonabee River near the former coal gasification plant site may be deposited in the more quiescent areas of the lake. The elevated levels at station OR-1 also suggest that some material from Little Lake is carried further downstream. However, these levels were generally low compared to concentrations in Little Lake.

PAH concentrations at station RS-1, at 165.5 ppm, were considerably higher than at any of the other sites. While deposition of coal tar wastes from known seepage areas upstream could be accumulating in this area, a number of other potential sources could contribute to PAH accumulation. These include the Rink Street storm sewer discharge, the presence of a recreational marina, as well as potential deposition of coal tar wastes from upstream. However, concentrations adjacent to a storm sewer discharge in Toronto's Ashbridges Bay, which receives primarily urban runoff reached a maximum of 51.8 ppm total PAH (Jaagumagi *et al* 1991). This is considerably lower than concentrations recorded at RS-1 and suggest that there are significant additional inputs at RS-1. Attempts at "fingerprinting" the PAH compounds and comparing the resulting pattern were inconclusive, and suggest a mixture of sources to this area.

While additional samples for PAH analysis were not collected downstream of OR-1, sediment bioassay samples from stations OR-6 and OR-7 were analyzed for PAHs (Table 8). Concentrations were below the LEL of 4 ppm at both sites suggesting little downstream movement of PAHs has occurred.

In comparison, studies in Thunder Bay harbour suggest that concentrations below 30 ppm total PAH resulted in no discernable effect on benthic communities (Jaagumagi *et al.* 1998). A similar result

was observed in bioassay tests.

Similarly, a study of a former wood distillation plant at South River (Jaagumagi 1992) found negative biological effects only at those locations where sediment concentrations of total PAH exceeded 50 ppm. The differences between the Thunder Bay study and the South River study could be readily accounted for by the higher TOC content of the sediments at South River (~100 mg/g) when compared to Thunder Bay sediment (~50 mg/g).

Since sediment organic matter has been shown to effectively bind organic compounds and thus limit their biological availability, the relatively high TOC content of Little Lake sediments (50-100 mg/g) should significantly limit the availability of PAH compounds from the sediments in Little Lake and the Otonabee River. Based upon other studies in areas of coal tar seepage from coal gasification plants, the concentrations encountered in Little Lake are not expected to result in any adverse effects on resident biota.

A similar argument could be made for sediment PCBs, the biological availability of which is also controlled by sediment organic matter. This will depend on the actual levels of toxic congeners in sediment.

4.2 Laboratory Sediment Bioassays

Spatial Trends in Sediment Toxicity and PCB Bioaccumulation

A ranking system was used to identify differences in sediment quality among sites for the four test sediments. This was determined by the magnitude of an effect using statistical test methods and total PCB minnow concentrations as they relate to existing federal and provincial tissue guidelines. Each endpoint was considered as being either a significant, toxic (T) or non-significant, non-toxic (N) response. In addition, the lethality endpoint received a greater weighting over the respective sublethal endpoint, where applicable. The final rating is based on the total number of positive hits recorded for each of the five biological endpoints along with the PCB bioaccumulation data. Each sediment fell into one of the following classifications (listed from least impacted (high quality) to most impacted (very low quality)): non-impacted (high); slightly impacted (slight); intermediately impacted (moderate); strongly impacted (low); and very strongly impacted sites (very low) (Table 11).

The final ranking of the Otonabee River sediments was mainly driven by the total PCB concentrations measured in the laboratory-exposed fish. From a toxicity point of view, the PCB sediment concentrations were not high enough to elicit either a lethal or sublethal effect. With only one positive hit, the poorest ranking reached was either slightly (station RS-1) or moderately (station OR-1) impacted. The highest minnow PCB concentrations were measured for these two sites (490 ng/g and 540 ng/g, wet weight) and were above the International Joint Commission (IJC) Aquatic Life Guideline of 100 ng/g (IJC, 1988) and fell just within the sport fish consumption restriction guidelines of 500 ng/g to 4,000 ng/g (MOEE/MNR, 1997). Station OR-1 received a poorer ranking due also to the fairly high degree of PCB availability (BSAF 7.0), as compared to station RS-1 (BSAF 2.3). The other two sites (station OR-6 and OR-7) had only marginal PCB sediment concentrations, at or below LEL concentration, and PCB tissue concentrations, at or below the federal tissue guideline. These sites were assigned a better ranking, even though the degree of PCB availability remained high (BSAF: 5.4 and 5.6). It should be noted that under certain circumstances, particularly long-term exposures experienced *in-situ,* the degree of PCB availability observed in the laboratory may serve as a warning of the potential for PCB to biomagnify at all four test locations.

Relationships Between Biological Endpoints and Sediment Physical/Chemical Characteristics

Spearman rank correlation coefficients were calculated between each test species and endpoint (Table 12). Very few significant correlations existed and the only one of any interest occurred between the benthic invertebrate growth responses ($r=-1.0$, $p<0.001$). This was a result of the opposite growth patterns seen at stations RS-1 and OR-7. Station RS-1 sediment yielded the best midge growth and yet also had the worst mayfly growth and vice versa for station OR-7. This disparity appeared to be linked to substrate type, specifically the percent sand content (Table 13).

The toxicity endpoints were also compared to

sediment physical, nutrient and chemical parameters to aid in determining potential causes for the observed laboratory effects (Table 13). As stated earlier, growth was affected by the physical attributes of the sediment e.g. % sand. Although midge and mayfly growth was correlated with substrate type, the differences in the body weights were not necessarily statistically significant (Table 9). Station RS-1 sediment is categorized as a sandy loam with a 50% sand content. Midge growth has been shown to be influenced by sediment type with a higher preference for sandier, hard-packed substrates (Ankley *et al.*, 1994). In fact, *Chironomus* sp. are quite tolerant of substrates comprised solely of sand and sandy substrates are commonly used for culturing purposes (Ingersoll and Nelson, 1990; ASTM, 1997). On the other hand, mayfly nymphs are typically associated with softer, less coarse sediments that provide a suitable substrate for burrowing. Mayfly growth appeared to be only slightly affected and only in very coarse sediments (>80% sand) does mayfly survival become compromised (Bedard, 1989; Bedard and Petro, 1992).

The largest number of positive correlations occurred between midge survival and six of the trace metals. This association is somewhat unexpected because it implies that midge survival actually increased as the sediment metals concentrations increased. The other parameter that was also correlated with midge survival was TOC, which in turn, was strongly correlated to As, Cd, Cr, Hg, Pb and Zn sediment concentrations. After correcting for differences in TOC, midge survival no longer correlated with any of the trace metals. It appears midge survival was responding to a greater extent to sediment nutrient content rather than the inorganic contaminant concentrations. Suedel and Rodgers (1994) demonstrated a minimum sediment TOC of 2.7% is required for promoting *Chironomus tentans* survival of >80%. For example, station OR-7 had the lowest amount of TOC (3.1%) and a 85% midge survival rate. Overall, midge survival rates did improve as the amount of TOC increased in the sediment.

Organic chemical sediment concentrations were a poor indicator of biological effect. The total PCB sediment concentrations were well below predicted effect-level concentrations, according to cited literature values. In 10-day sediment toxicity tests using the marine amphipod, *R. abronius*, a LC50 of 10.8 µg/g (2,600 - 4,500 µg/g OC) was estimated for PCB spiked-sediments by Swartz *et al.*, (1988) and > 27.4 µg/g (> 2,560 µg/g OC) by Murdoch *et al.*, (1997). In comparison, the highest PCB sediment concentration in the Otonabee River sediments was 1.4 µg/g or 29 µg/g OC. Sediment toxicity tests that were conducted in 1987 for 15 sites in the Otonabee River and Rice Lake also found a lack of organism toxicity at similar exposure concentrations (Jaagumagi and Petro, 1991). In the 10-day tests, using mayflies and fathead minnows, organism mortality never exceeded 20% and total PCB sediment concentrations were less than 1.3 µg/g (18 µg/g OC) for 14 of the 15 test sediments.

The likelihood of eliciting a significant sublethal effect was also marginal. In a recent study on freshwater sediments collected from Lyons Creek, near Welland, Ontario, using similar test methods as those described herein, sublethal effects were associated with total PCB sediment concentrations greater than 1.0 µg/g (> 27 µg/g OC) (Bedard and Petro, 1998). Similarly, *Chironomus tentans* growth impairment occurred in 10-day toxicity tests on Detroit River sediments with PCB sediment concentrations ranging from 1.2 to 6.1 µg/g or 30 µg/g OC to 121 µg/g OC (Besser *et al.*, 1996).

Importance of PCB Bioavailability and Bioaccumulation

Biota-sediment accumulation factors (BSAFs) were calculated as a measure of the relative availability of total PCBs from sediment to fish. A BSAF of >1.0 indicates that the concentration of chemical found in the organism exceeds the concentration in the bulk sediment. In the 21-day tests, fathead minnow PCB concentrations were 2-times to 8-times higher than those measured in the sediment and are indicative of chemical bioaccumulation. The BSAFs were substantially higher after normalizing for sediment organic carbon content and fish lipid content. The normalized BSAFs ranged from 8.5 to 29.1. According to the screening level of 4.0 that was developed by the USEPA (1991), for the risk assessment of highly persistent compounds in dredged material, each of the test sediments surpassed this value. The above normalized BSAFs were based on an average lipid content of ~1%, which is much lower than cited percent lipid values of ~5%, for juvenile fathead minnows. The extraction solvents used in the determination of lipid content in biota can affect the

total amount of lipid removed and will inflate BSAFs (Honeycutt *et al.*, 1995). Even the revised BSAFs indicated a high availability of PCBs from sediment to fish for all of the Otonabee River sites (BSAF: 5.4 to 7.0).

The Little Lake sediment showed reduced bioavailability (BSAF: 2.3) relative to the other test sediments and may be due to several factors. The organic matter found in Little Lake sediments may have different characteristics than that associated with the Otonabee River, thereby altering the sediment's absorption properties. Another possible explanation could be a reduced exposure by minnows to PCB-contaminated sediments due to the lack of sediment re-suspension in the station RS-1 test jars. Despite the lower PCB availability for station RS-1, the fathead minnows still attained the highest PCB tissue concentration. Hitchin (1997) also observed a difference in young-of-the-year yellow perch and spottail shiner PCB tissue concentrations between samples collected in Rice Lake, at a site near the mouth of the Otonabee River (348 - 476 ng/g) and in Little Lake, near the Rink Street sewer (100 - 124 ng/g).

Several laboratory studies have shown PCBs to be highly bioaccumulative from contaminated sediments to biota. The normalized BSAFs measured for the Otonabee River sediments (BSAF: 2.3 to 7.0) agree favourably to those found for mayflies, 5.0 to 9.2 (Drouillard *et al.*, 1996), molluscs and polychaetes, 2.6 to 4.9 (Lake *et al.*, 1990) and juvenile fathead minnows, 2.9 to 7.8 (Bedard and Petro, 1998). The uptake of PCBs can be initially described as a partitioning of the chemical between the organic carbon fraction of sediment and the lipid portion of the animal. This simple chemical partitioning can account for BSAFs that average 1.7 (Konnemann and Van Leeuwen, 1980; McFarland and Clarke, 1986). As mentioned previously, the potential sources of PCBs to fathead minnows could include the direct ingestion of sediment particles during feeding and foraging, contact with suspended particulates and water-borne uptake through the gills (Dabrowska *et al.*, 1996). Higher BSAFs can be achieved due to multiple routes of chemical uptake (Lee, 1992). Gobas *et al.*, (1993) developed a fugacity model that describes enhanced chemical bioaccumulation can occur during the active ingestion of contaminated material through the gut. This process can account for BSAFs >3.5 (Gobas *et al.*, 1989). This phenomenon has been confirmed both for predator/prey interactions (Russell *et al.*, 1995) and benthos/sediment interactions (Boese *et al.*, 1996).

4.3 Mussel Biomonitoring

4.3.1 PCBs

Mussel exposure studies first undertaken in 1985 identified the Park/Cameron and the Rink Street sewers as major sources and the Romaine Street sewer outfall and STP as minor sources of PCBs in the Peterborough area (Maude *et al.* 1992). The results of this study are consistent with the previous studies (Figure 11) which found that the Rink Street and Park/Cameron Street sewers are active sources of PCBs and that PCB concentrations in mussels, after declining markedly in the mid to late 1980s have declined only marginally since then. PCB concentrations in mussels at the minor sources appear to be unchanged, fluctuating between below and just above the detection limit.

Statistically, the mussels exposed in the Park/Cameron St. sewer outfall had the highest PCB concentrations, followed by mussels exposed at the two stations in the receiving water near the Rink Street sewer outfall. However, the mussels at the Park/Cameron Street outfall were in the actual discharge as opposed to the receiving water. If a comparison is to be made of the relative significance of the two sources of PCBs it would be more appropriate to compare the mussels exposed at the station located approximately 10 m downstream of the Park/Cameron Street discharge (Station 13) to the mussels exposed near the Rink Street sewer (stations 6 and 7). Based on Tukey's HSD test, mussels at the Rink Street sewer outfall are significantly higher in PCBs than mussels downstream of the Park/Cameron Street sewer. Therefore, it is likely that of the two primary sources, the Rink Street sewer was of greater environmental significance during the three week exposure period.

At both Rink Street and Park/Cameron Street mussels were placed close to the storm sewer discharges in areas of high flow, devoid of fine-grained sediments. Since PCBs tend to be associated with fine-grained sediments, it is unlikely that the PCBs in mussels came from sediments contaminated in previous years Furthermore, mussel biomonitoring studies

undertaken elsewhere indicate that PCBs tend to be taken up from the water column rather than historically-contaminated sediments.

Station 3 which had not been sampled previously is located approximately 600 m upstream of the Rink Street sewer outfall was found to have low levels of PCBs in mussel tissue (40 ng/g). In a previous study in 1986 (Maude *et al.* 1992), similar levels of PCBs were found in mussels exposed near the mouth of Jackson Creek. At the time they were attributed to eddy currents during the construction of Crary Park. Although the levels were low in both cases, in future studies additional samples should be taken to determine if there is a source.

4.3.2 PAHs

PAHs are rapidly metabolized and excreted by most vertebrates. However, mussels accumulate PAHs in their tissues and excrete them only very slowly. The rate of excretion of PAHs is variable. Small PAH molecules such as naphthalene have a short biological half-life in mussels (days), whereas larger molecules tend to have a much longer half-life. Previous MOE studies have found PAHs in mussels at sites known to have active discharges of PAHs or where historic non-weathered PAHs were entering a water body. In the Otonabee River near Peterborough the PAHs do not appear to be entering the water column, otherwise detectable concentrations would have been found in mussels.

4.4 Sport Fish Contaminant Monitoring

4.4.1 Sport Fish

There is an extensive database for sport fish in the Otonabee River system. Testing in the 1970s found carp exceeded the Federal regulatory limit of 2000 ng/g PCBs and the commercial sale of this species was banned. Until 1995, MOE used the Federal regulatory limit to provide consumption advice to anglers in the Guide to Eating Ontario Sport Fish. Sport fish with PCB concentrations below 2000 ng/g were considered acceptable for unlimited consumption. Above 2000 ng/g, fish were considered to be unacceptable for consumption by women of childbearing age and children under 15. Others were advised to consume only limited quantities of these fish (1 or 2 meals per month). The use of the Federal Regulatory limit assumed that only moderate quantities of fish were being consumed. Starting with the 1995 Guide, an approach was instituted which would protect all sport fish consumers, including those who consume large quantities of fish. The approach utilizes a tolerable daily intake and results in a sliding scale of recommended fish consumption based on contaminants in the fish. It is described in more detail in the Guide to Eating Ontario Sport Fish (1997).

The tolerable daily intake values used by MOE are developed by Health Canada and are subject to change as new toxicological information becomes available. Currently, Health Canada's tolerable daily intake for PCBs is 1 ug/kg body weight/day, with 50% allocated to fish consumption. Based on the assumptions that the average adult body weight is 60 kg and average meal size is 227 g, sport fish consumption is not restricted for fish with less than 500 ng/g PCBs (assuming that sport fish consumption does not exceed eight meals per month). Consumption of sport fish is restricted to 4 meals per month for sport fish with 500 ng/g and 1000ng/g PCBs, 2 meals per month between 1000 ng/g and 2000 ng/g, 1 meal per month between 2000 ng/g and 4000 ng/g and no consumption above 4000 ng/g. Women of childbearing age and children under 15 are advised not to consume any fish over 2000 ng/g.

The concentration of PCBs in fish varies among species and locations. Fish from many areas of the Great Lakes have high levels of PCBs. The primary contaminant resulting in consumption restrictions is PCBs for all of the Great Lakes except Lake Superior. However, even in many Great Lakes locations, species such as walleye, northern pike, and bass do not have detectable levels of PCBs (<20 ng/g). High levels are usually found in species such as trout, salmon, bullheads and carp, which have a higher fat content and are thus able to accumulate higher levels of PCBs.

Inland waterbodies rarely have restrictions on fish consumption because of PCBs. Whereas over 50% of the consumption restrictions on Great Lakes fish is because of PCBs, less than 1% of the restrictions in inland waterbodies are caused by PCBs.

With the exception of the Otonabee River/Rice Lake system, the lakes and rivers in the general vicinity of Peterborough have fish that are low in all contaminants including mercury and chlorinated organic compounds such as PCBs. Mercury concentrations in fish in the area are among the lowest found anywhere in Ontario. However, some of the larger specimens of predatory species such as walleye and bass do have consumption restrictions because of mercury.

The sport fish consumption advisories described below are based on current Health Canada guidelines. They are slated to be included unchanged in the next issue of the Guide to Eating Ontario Sport Fish (March 1999), provided that, in the interim, the guidelines do not change and additional data are not collected.

4.4.2 Spatial and Temporal Trends in PCBs

Otonabee River – Upstream of Peterborough

Historically, sport fish upstream of the primary sources of PCBs have had non-detectable or trace concentrations of PCBs in their tissue. Similarly, in this study walleye, smallmouth bass and brown bullhead all had non-detectable concentrations of PCBs (Table 17). The individual carp collected at this location was the only exception and had 40 ng/g Typically, trace levels of PCBs (<20-100 ng/g) are found in carp in uncontaminated waterbodies. Currently there are no sport fish consumption advisories upstream of Peterborough because of PCBs, nor will there be any resulting from this study.

Otonabee River – Little Lake

Unfortunately there is little historical sport fish data for Little Lake. Prior to this study, PCBs were last analyzed in Little Lake sport fish in 1982. Concentrations found in smallmouth bass at that time ranged from not detectable to 540 ng/g. In the current study, concentrations were lower, ranging from 40-80 ng/g. Carp had not been sampled at this location prior to this study. Only one carp was sampled and had 240 ng/g PCBs. Additional carp are required for analysis, otherwise consumption advice on this species cannot be provided to anglers. Walleye from Little Lake were elevated, ranging between 80-280 ng/g. Anglers will not be advised to restrict consumption of walleye because of PCBs.

Considering the proximity of this sampling location to the source of PCBs and the concentrations found downstream in sport fish, the levels of PCBs in sport fish are low. There are a number of possible reasons for this. Fish at this location are subjected to PCBs from only one of the two primary sources and are also free to move upstream, out of the influence of the Rink Street sewer discharge. Also, there is some evidence that there is a reservoir of PCBs in sediments downstream in the Otonabee River and Rice Lake that may be contributing to the higher concentrations found there in sport fish. In future studies, congener-specific PCB analysis of sport fish tissue may prove useful in determining why concentrations of PCB in sport fish at this location are lower than downstream.

Otonabee River – Bensfort Bridge

Historically, some species of sport fish in the Otonabee River at Bensfort Bridge had elevated levels of PCBs. Carp were analyzed in 1985 and consumption was restricted to 2 meals per month at 45 cm, 1 meal at 55 cm and no consumption advised over 65 cm. Consumption restrictions on carp collected in 1996 (which will be in the 1999 Guide) are only marginally less contaminated. Consumption will be restricted to 4 meals per month at 45 cm, 2 meals at 55 and 1 meal at 65 cm.

Walleye in 1985 had elevated levels of PCBs and anglers were advised to restrict consumption. In the 1997-8 Guide, consumption of walleye is not restricted up to 55 cm. Between 55 and 65 cm consumption is restricted to 4 meals per month. Consumption of walleye over 55 cm was restricted because both PCBs and mercury exceeded the consumption limit. In this study, walleye up to 54.3 cm were collected and found to be acceptable for unrestricted consumption and therefore the advice in the 1999 Guide will be the same as in the previous Guide, up to 55 cm. Since walleye between 55 and 65 cm were not tested, and other data suggest only a marginal improvement in PCBs and no change in mercury, consumption advice between 55-65 cm will remain the same (i.e. consume no more than 4 meals per month).

In 1996, brown bullhead, smallmouth bass and largemouth bass all had elevated levels of PCBs but not enough to result in consumption restrictions. Black crappie was the only species with non-detectable concentrations of PCBs.

Rice Lake – Mouth of Otonabee River

The most comprehensive set of sport fish data is from Rice Lake at the mouth of the Otonabee River. PCBs were measured in carp in 1984, 1985, 1987, 1989, 1991 and 1996. Concentrations of PCBs in carp have not changed substantially of the period of sampling (Figure 12). The consumption advisory in the 1999 Guide will be as follows: unlimited consumption up to 35 cm; 4 meals per month between 35 and 55 cm; 2 meals per month between 55 and 65 cm; and 1 meal per month for all carp over 65 cm.

The concentration of PCBs in walleye in 1996 is also similar to that found in previous years. The consumption advisory in the 1999 Guide will be less restrictive and permit unrestricted consumption of walleye up to 55 cm compared to 45 cm in the current Guide.

In the current issue of the Guide, consumption of brown bullhead and largemouth bass is restricted because of PCBs. Although the concentration of PCBs in these species remain elevated, the consumption restrictions will be removed in the 1999 Guide because PCBs do not exceed the 500 ng/g consumption limit.

Rice Lake – East end

At the east end of Rice Lake, carp, walleye, brown bullhead and largemouth bass all had detectable concentrations of PCBs. Carp is the only species currently with a consumption restriction (4 meals per month at 55-65 cm). In the 1999 Guide, consumption will remain restricted for this size range as the PCB concentration in carp is essentially unchanged from 1991.

Trent River Downstream of Rice Lake

At Seymour Lake, which is the first lake downstream of Rice Lake, PCBs are elevated in fish. Carp, which were sampled for the first time, have PCB concentrations high enough to restrict consumption (Table 17). Carp are acceptable for unlimited consumption up to 65 cm. Between 65 and 75 cm, the consumption of carp is restricted to 4 meals per month.

Further downstream at Percy Reach, PCBs are elevated but no consumption restrictions are currently in place, nor will there be any in the 1999 Guide.

4.5 Young-of-the-Year Fish

Canadian Tire

In previous years, fish have been difficult or impossible to collect at this site. Higher priority has been given to downstream sources in recent years. Fishing success was poor in 1996 at the Canadian Tire site on the west shore. Since perch were not available, spottail shiners were collected. Although spottail shiners may not be directly comparable to yellow perch (habitat preference, available food, etc), results at the Canadian Tire site indicate a significant decrease in PCB levels in juvenile fish over an 11 year period, from 620 ± 35 ng/g in 1985 to 80 ± 0 ng/g in 1996.

Rink Street

PCB concentrations in perch collected at Rink Street were negatively correlated with time (Figure 15). PCB residues in perch at Rink Street have declined 8-fold over the period from 1980 to 1996 from 865 ± 149 ng/g in 1980 to 100 ± 28 ng/g in 1996. Contaminant levels in 1996 are at the IJC Aquatic Life Guideline (GLWQA 1978) of 100 ng/g for the protection of piscivorous wildlife. PCB concentrations in yellow perch are similar to those in spottail shiners.

Beavermead

Significant reductions of PCBs in perch were observed over the period 1982 to 1996 at the Beavermead site (Figure 15). Although PCB levels fluctuated in the 1980s, concentrations have declined steadily in the 1990's, to the point where the 1996 collections were below the IJC guideline (72 ± 23 ng/g) for the first time.

Below STP

Perch collected below the STP, just above Hwy 7, were considerably larger in 1996 than in previous years. These fish are likely 2-3 years old and could range over a much larger area, with the potential

to access other contaminated sites in the river. PCB residues in perch caught below the STP ranged between 1000 - 1500 ng/g in the 1980's. Collections in 1996 were significantly reduced (352 ± 103 ng/g), but still well above the IJC Aquatic Life Guideline.

Spook Island

PCB declines in yellow perch collected in Rice Lake at Spook Island were significantly, negatively ($P > 0.05$) correlated with time (Figure 16). PCB residues in perch continue to fluctuate over time and remained well above the IJC Aquatic Life Guideline in 1996 (476 ± 46 ng/g) . Reasons for elevated PCBs in 1995 (916 ± 126 ng/g) are unknown. Total PCB residues in perch collected in recent years in Rice Lake may be driven by in-lake physico-chemical factors, in addition to PCB loadings from Peterborough (eg. resuspension of contaminated sediments in Rice Lake and uptake of contaminants to fish during storm events).

Seymour Lake

PCB residues in perch in Seymour Lake declined from (203 ± 38 ng/g) in 1987 to (120 ± 24 ng/g) in 1996, well below levels observed at Spook Island in 1996. Contaminant levels in yellow perch and spottail shiners were similar.

5.0 CONCLUSIONS

Sediment sampling has shown that PCBs are broadly distributed throughout the Otonabee River-Rice Lake system, from Little Lake to the Trent River. Surficial sediment concentrations up to 1.4 ppm have been encountered in a number of locations, while subsurface concentrations ranged up to 2.4 ppm. No identifiable "hotspots" of sediment contamination were noted during this survey.

Biological effects testing showed that there are no lethal or sublethal effects evident on the sediment bioassay test organisms at concentrations typically encountered in Otonabee River and Rice Lake sediments. However, the fathead minnow test does confirm that PCBs are available from the sediments. PCB levels in tissue at the end of the 21 day test were above sediment concentrations, which indicates that PCBs are readily available from sediment.

The biological data show a general lack of toxic responses among the test organisms. Laboratory sediment bioassays typically exemplify a "worst case" scenario, since in the process of conducting the test, sediments are resuspended, potentially increasing the availability of any bound contaminants. Under natural conditions, which, it must be noted, would likely include seasonal periods of sediment resuspension, a similar or lesser response would be expected. As such, the bioassay tests likely approximate yearly conditions in the Otonabee River-Rice Lake system.

The bioassay tests do show that PCBs are bioavailable from the sediments and are accumulated to levels higher than those encountered in the sediments. This has implications for transfer of contaminants through the food web.

Results of the young-of-the-yearfish sampling indicate that tissue residues in yellow perch from Little Lake in 1996 were between 72 and 100 ng/g at Beavermead and Rink St respectively. This represents a decline from 1980, when levels in fish tissue were 865 ng/g at Rink St. In contrast, levels in yellow perch at Spook Island in Rice Lake averaged 476 ng/g in 1996, which was well above the IJC Aquatic Life Guidelines of 100 ng/g for the protection of fish-eating wildlife. The level of 476 ng/g represented a significant decline over levels in 1977, which averaged over 1300ng/g. However, the rate of decline in Rice Lake fish has slowed considerably since 1992 .

Sport fish data show that PCB residues in carp have not changed since 1984, and there are still consumption restrictions on carp. The elevated levels in carp tissue are likely the product of their feeding behavior. Since carp are bottom feeders, they are more likely to come into direct contact with contaminated sediments through both disturbance of the sediments as they feed, as well as through ingestion of benthic organisms that may be contaminated with PCB residues. PCB residues in other species appear to have declined marginally between 1984 and 1996.

The results of the sediment bioassay testing, the young-of-the-year fish analysis and the sport fish contaminants monitoring program all suggest that the availability of PCBs in the Otonabee River-Rice Lake system is still relatively high. Given that Rice Lake is

a relatively shallow lake which would experience considerable re-suspension of bottom sediments, it is anticipated that the potential for burial of contaminated sediments by deposition of cleaner material is relatively low. In addition, the large reservoir of PCB contaminated sediments currently contained within Little Lake and the lower Otonabee River could contribute PCB contaminated sediments to Rice Lake for many years through re-suspension and transport down-river. While the data suggests that at some locations in the Otonabee River cleaner material overlies more contaminated sediments, there are a number of locations in the river where the reverse seems to be true. This suggests that re-suspension and transport are still active processes redistributing PCB contaminated sediments within the system.

Finally, the clam biomonitoring data suggest that there are still inputs to the system through the Rink St sewer and the Park St sewer, and to a lesser extent, through the Romaine St sewer. Concentrations in clams have fluctuated over the years, but are generally much lower than in 1986.

We would anticipate, based on existing trends, and the extent and availability of sediment bound PCBs, that the fish consumption restrictions currently in place for carp would continue into the foreseeable future.

PAH distribution suggests that historical losses from the former coal gasification plant located adjacent to the Otonabee River upstream of Little Lake have contributed to elevated levels of PAH compounds in sediments in Little Lake (the PAH investigation focused solely on the aquatic environment, and does not address any existing contamination on the site). High levels were encountered near the Rink Street sewer outfall, only part of which can be readily accounted for through discharge through the storm sewer system. However, despite the high levels of PAHs, there were no detectable biological effects either in the mussels or in the laboratory sediment bioassays, suggesting that these compounds are relatively unavailable. In contrast, levels in Little Lake were relatively low and appeared to result in no detectable biological effects.

Summary

1) PCBs in sediments are broadly distributed in the Otonabee River-Rice Lake system. Elevated levels are found at the Rink St. sewer outfall, and persist down to the Trent River. There appears to be little change in surficial sediment concentrations when current levels are compared to results from previous studies. Distribution of PCBs with depth suggests that at many locations, deposition has been higher in the past

2) With the exception of the area immediately adjacent to the Rink St sewer, moderate levels of PCBs were encountered in sediments throughout. Surficial concentrations were all below the SEL and ranged up to 1.3 ppm in Otonabee River sediments and up to 2.4 ppm in subsurface layers. This is similar to levels encountered in Rice Lake during previous surveys.

3) Bioassay testing found no direct toxicity, either lethal or sublethal, associated with sediment concentrations of PCBs. Laboratory uptake studies did find that PCBs were available from sediments, and were being accumulated in fathead minnow tissues to levels higher than in the sediment.

4) The young-of-the-year fish monitoring program found PCB levels in juvenile yellow perch from Rice Lake in 1996 to be above the IJC Aquatic Life Guideline. However, the trend in PCB levels from 1980 to 1996 indicates that levels are declining and that levels in 1996 were the lowest recorded. Results of the sediment bioassay testing indicate that sediment PCBs are likely contributing to tissue residues in young-of-the-year fish.

5) Sport fish monitoring program results indicate that levels in carp have declined only marginally, if at all, from levels in the 1970's. Tissue residues in young-of-the-year fish and sports fish will likely continue for some time. Rice Lake is relatively shallow and surficial sediment will be susceptible to resuspension during storm event, etc. This will continue

mixing the top layers and will slow down any potential burial of PCB contaminated material. As a result, PCBs will continue to be available to water column and sediment-feeding organisms.

6) Clam biomonitoring studies conducted in 1996 shows that the Rink St and Park St sewers are still sources of PCBs. However, levels were lower than in 1986.

7) Little Lake and Otonabee River will continue to act as a low level source of PCBs. Deeper layers had higher concentrations which will make any remedial action that requires sediment removal difficult to deal with. Attempts at removal could resuspend material that is more contaminated than what is currently moving down the river.

8) PAHs appear to be a limited problem. While elevated levels were found in Little Lake and Otonabee River sediments, these are not having any detectable effect on aquatic biota. PAHs appear to have accumulated to high concentrations near the Rink Street sewer. It is not clear whether the high levels are due to discharges from the sewer, or whether they are due to deposition of coal tar wastes seeping into the river from upstream areas. The area near the Rink St. sewer forms a small backeddy which would be favourable to deposition of suspended matter from upstream. Bioassay testing found no detectable biological effects associated with this material.

9) Based on sport fish, juvenile fish and clam biomonitoring data there does not appear to be a source of PCBs upstream of Rink Street.

10) PCBs in sport fish from the vicinity of Little Lake have elevated levels of PCBs but the levels are not high enough to result in consumption advisories. PCBs are lower at this location than further downstream below Highway #7.

11) Downstream of Highway #7 at Bensfort Bridge, sport fish have elevated levels of PCBs and consumption advisories will be issued in the Guide to Eating Ontario Sport Fish. There appears to be some decline in PCB concentrations in fish over time.

12) In Rice Lake at the mouth of the Otonabee River PCB concentrations remain elevated and consumption restrictions will be reissued for walleye and carp. Consumption restrictions on brown bullhead and largemouth bass will be dropped. PCBs in some species appear to have declined marginally over the period 1984-1996.

13) At the east end of Rice Lake, consumption restrictions on carp will remain in effect. PCBs appear to have declined marginally over the period 1987-1996.

14) Carp from Seymour Lake are elevated in PCBs and consumption restrictions will be issued. Further downstream at Percy Reach there are no restrictions on carp or any other species because of PCBs.

15) Overall in the Otonabee River/Rice Lake system, there appears to be a decline in the concentration of PCBs in sport fish. However, consumption restrictions remain in effect for one or more species at each sampling location downstream of Peterborough in the Otonabee River and Rice Lake.

6.0 RECOMMENDATIONS

1. PCBs continue to enter the system through the Rink St, Park St. and Romaine St. sewers. Effective source control efforts need to be continued to eliminate the source(s) of PCBs to the Otonabee River - Rice Lake system.

2. Given the extent of PCB contamination of the sediments and the associated biological effects, it is impractical to consider removal of sediment. The volume of material affected is extremely large and removal would be of very limited biological benefit. Active disturbance could, in fact, aggravate the problem by increasing the availability of PCBs currently bound in the deeper layers of

the sediment.

3. Localized dredging within the Otonabee River - Rice Lake system for navigation purposes will have to incorporate upland disposal or confined disposal. Side-casting or open water disposal cannot be considered due to the elevated levels of PCBs. The limited number of stations sampled suggests that, in general, most material would pass the Residential/Parkland classification of the Guideline for Use at Contaminated Sites in Ontario.

4. Previous studies have identified high PCB concentrations in the area adjacent to the Rink St. sewer. High PAH concentrations were noted during this study. As a result, development of a management plan should be undertaken for this area to address both the PCB and PAH contamination. Given the current recreational use of this area, the plan should address the entire marina.

5. Sediment sampling should be undertaken every 5 to 10 years to monitor any changes in PCB distribution. Effective source control should reduce loadings with the result that, over time, downstream areas should experience deposition of cleaner sediment in the surface layers.

6. Sport fish should be collected on a regular basis to monitor the levels of PCBs and to provide up-to-date consumption advice to anglers.

7. Sport fish should be analyzed for congener-specific PCBs to assist in determining the source(s) of PCBs.

8. Mussel exposure studies should be undertaken on a regular basis to monitor PCB trends until effective source control has been achieved.

9. Juvenile fish monitoring studies should be undertaken on a periodic basis to continue tracking trends in PCB levels.

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Figures

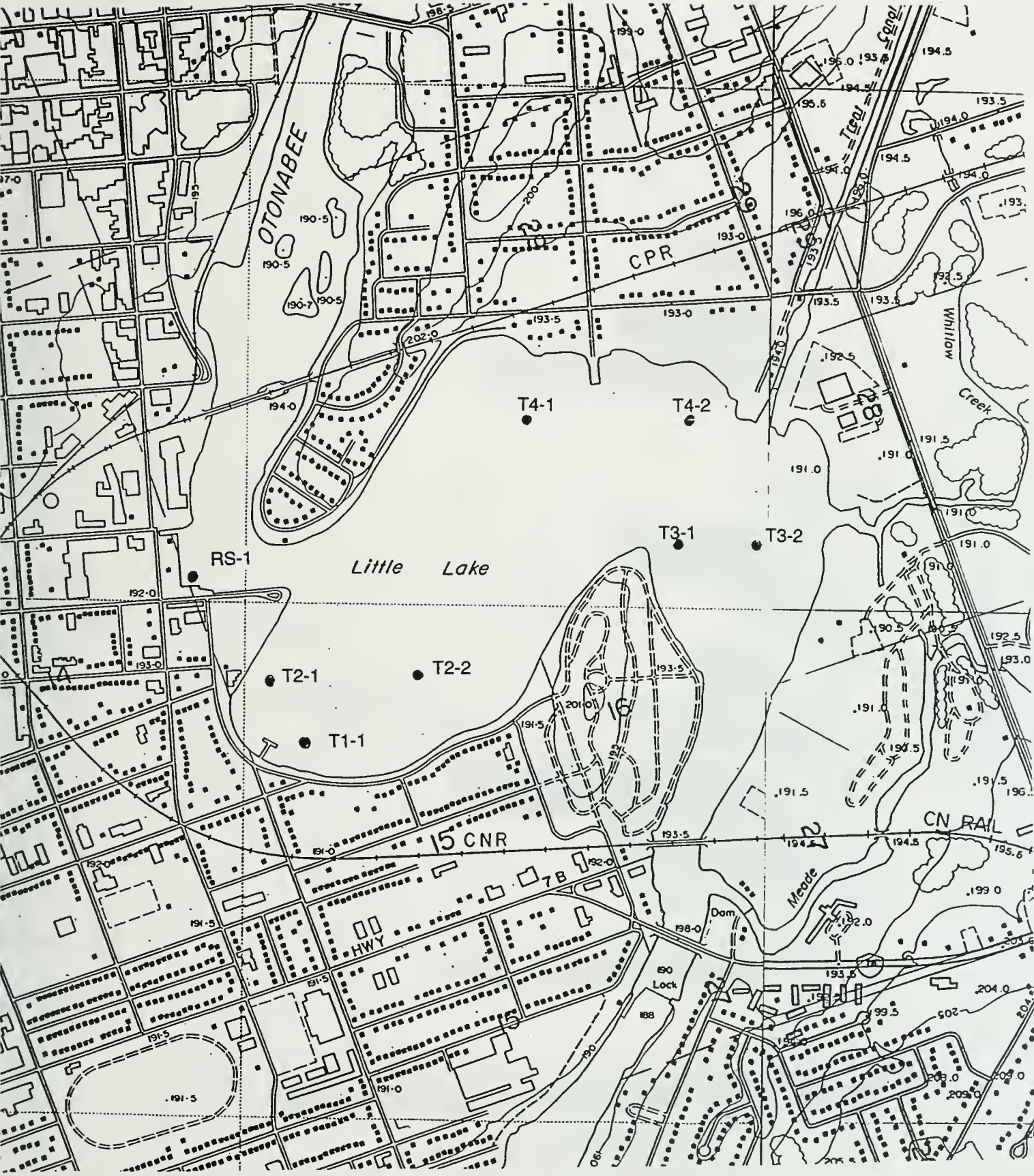


Figure 1: Location of Sediment Sampling Sites. Little Lake, 1996.

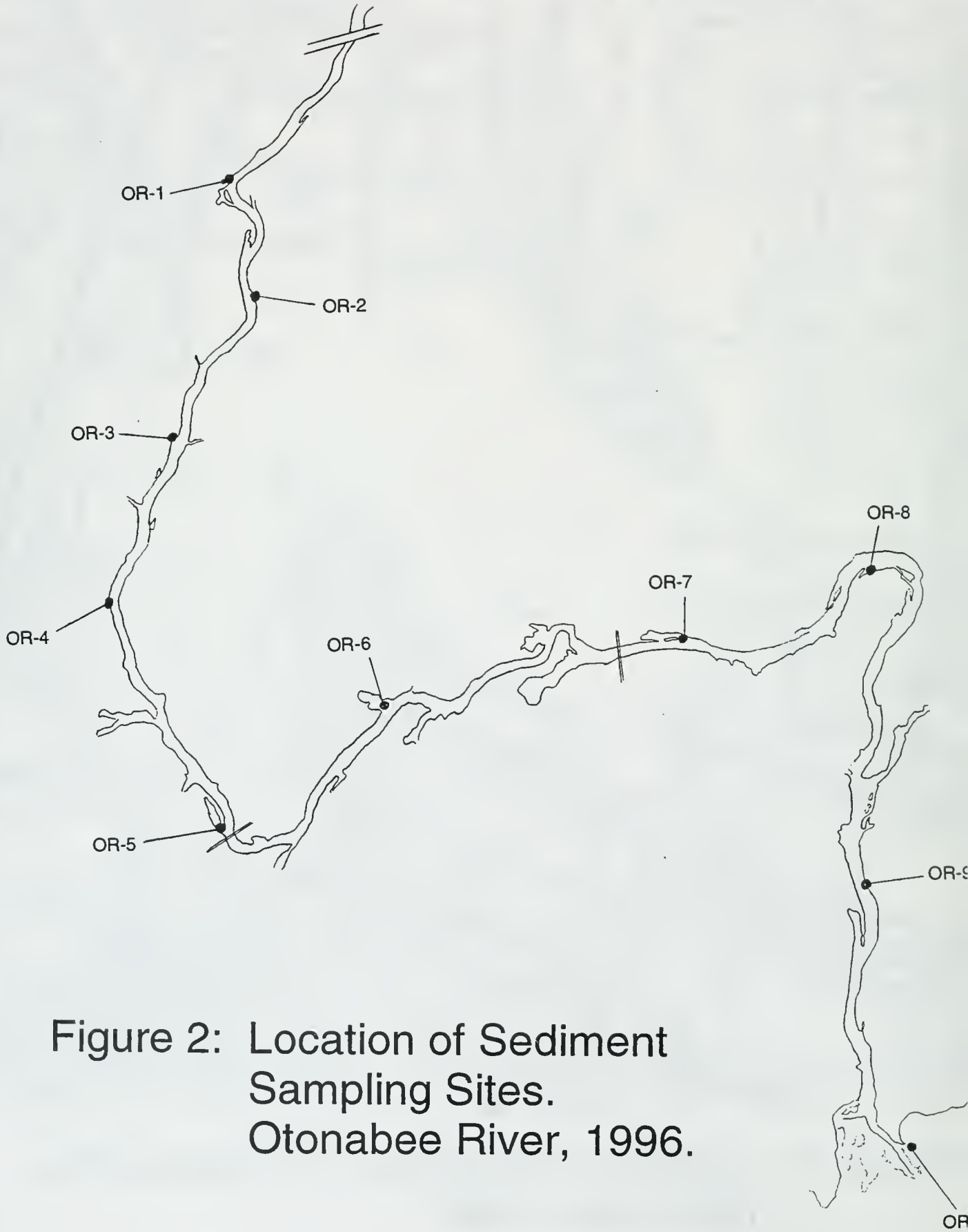


Figure 2: Location of Sediment Sampling Sites. Otonabee River, 1996.

Figure 3: PCBs in Little Lake Sediments

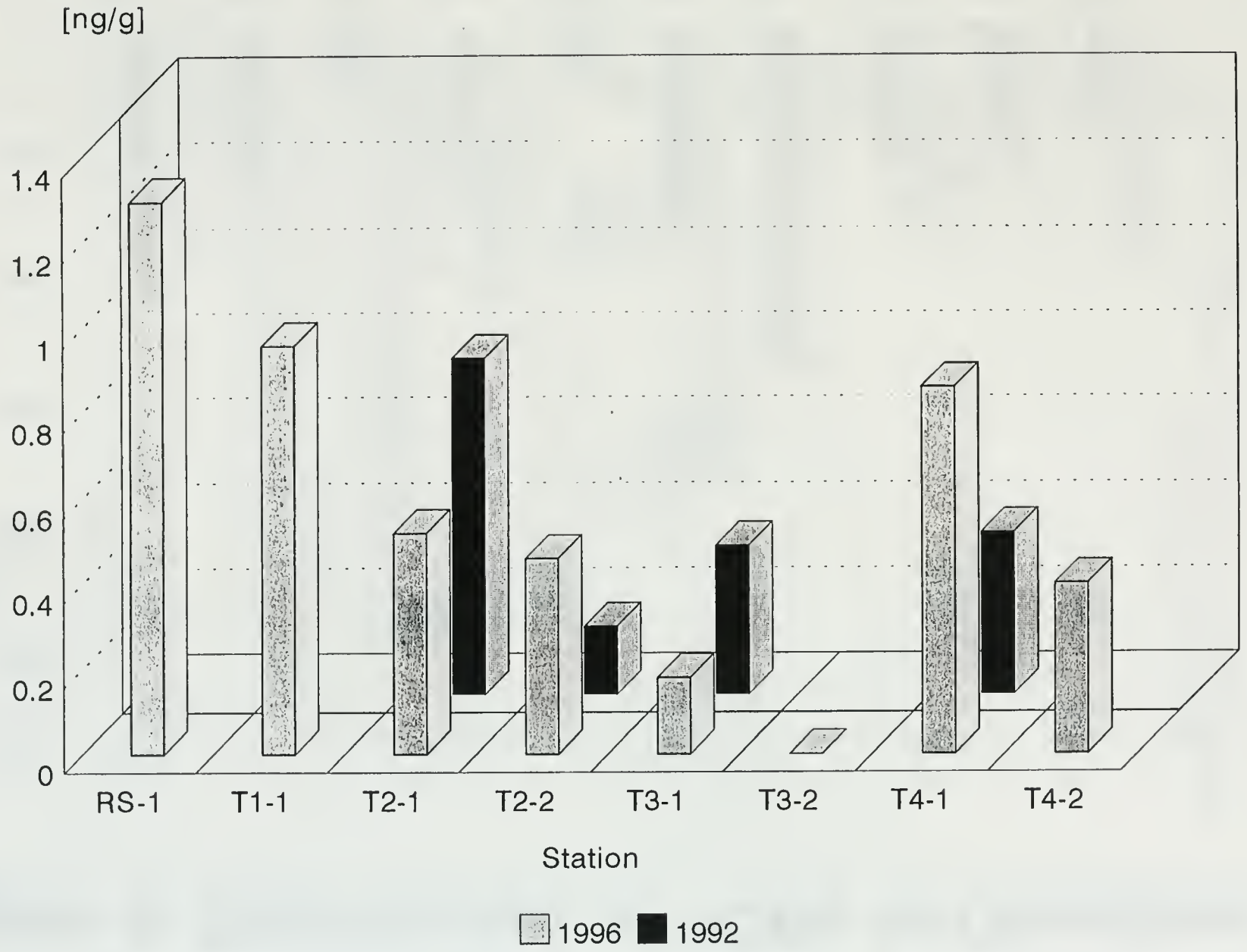
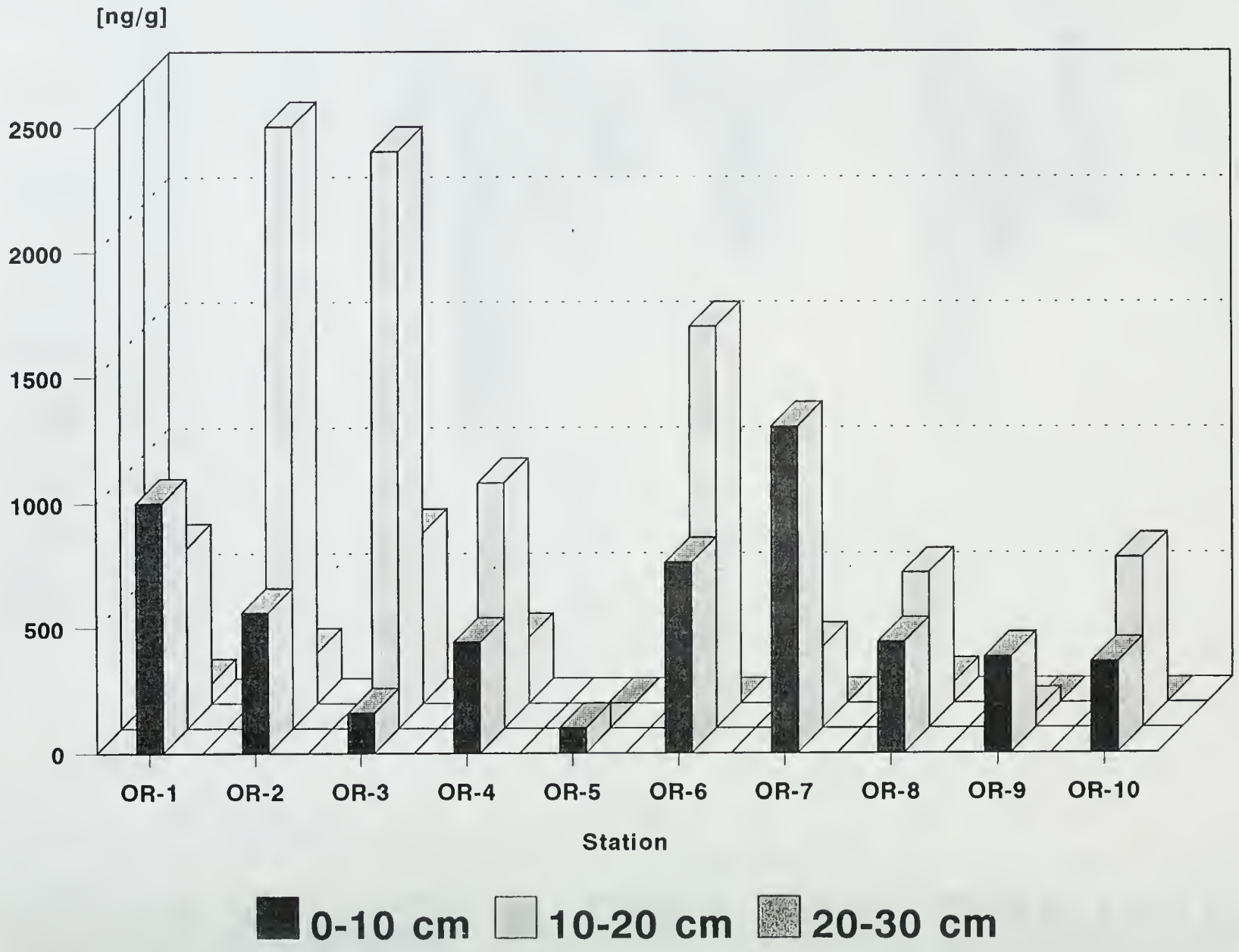


Figure 4: Distribution of PCBs in Otonabee R.



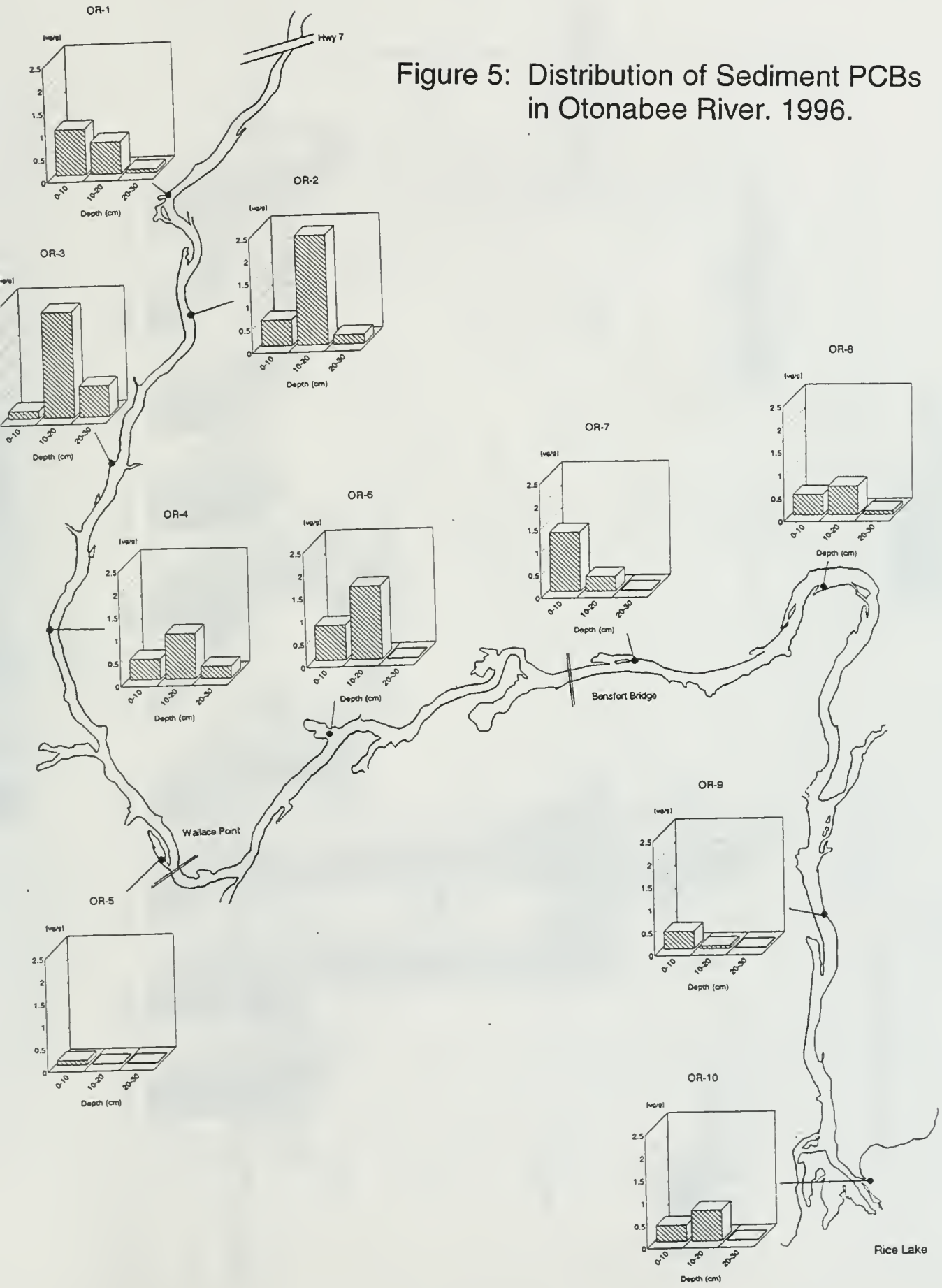


Figure 5: Distribution of Sediment PCBs in Otonabee River. 1996.

Figure 6: Sediment PCB Concentrations on Organic Carbon Basis

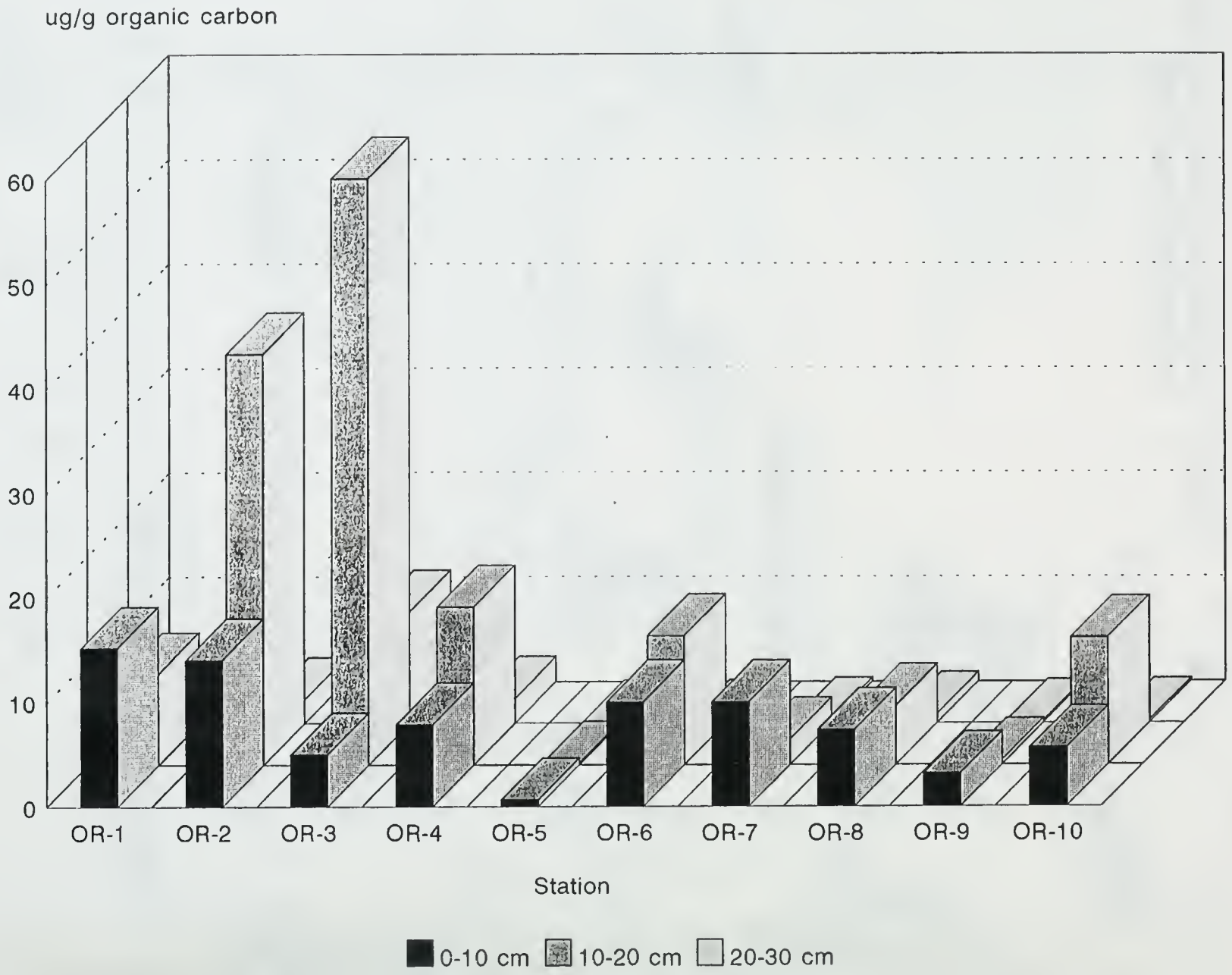


Figure 7: Distribution of PCBs in Rice Lake Sediment Cores. 1992

Environment Canada (P. Mudroch)

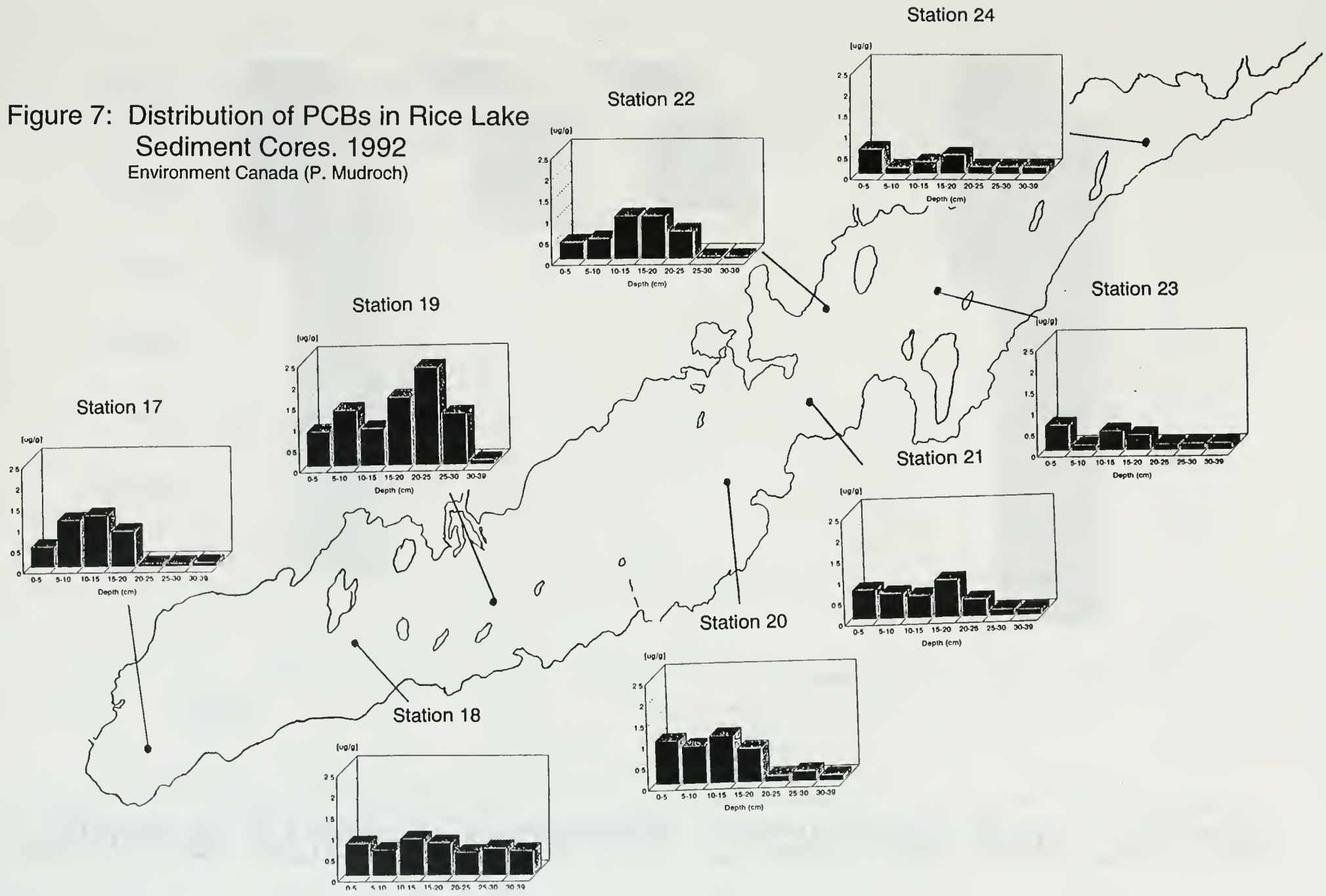


Figure 8: PCBs in Bioassay Sediments and Tissues

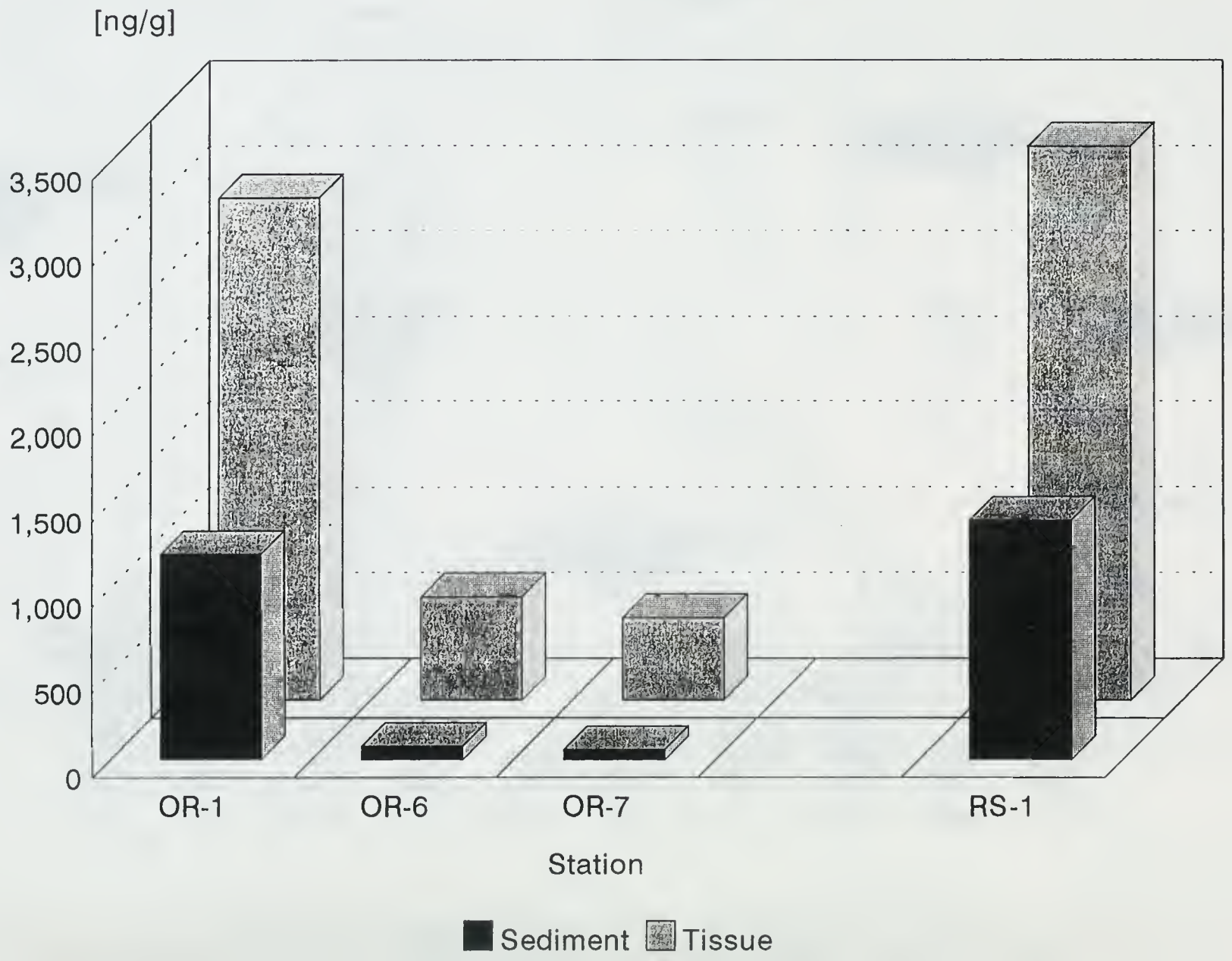


Figure 9: Distribution of PCB in Rice Lake Surficial Sediments. 1987-1992.
(Environment Canada & MOE)

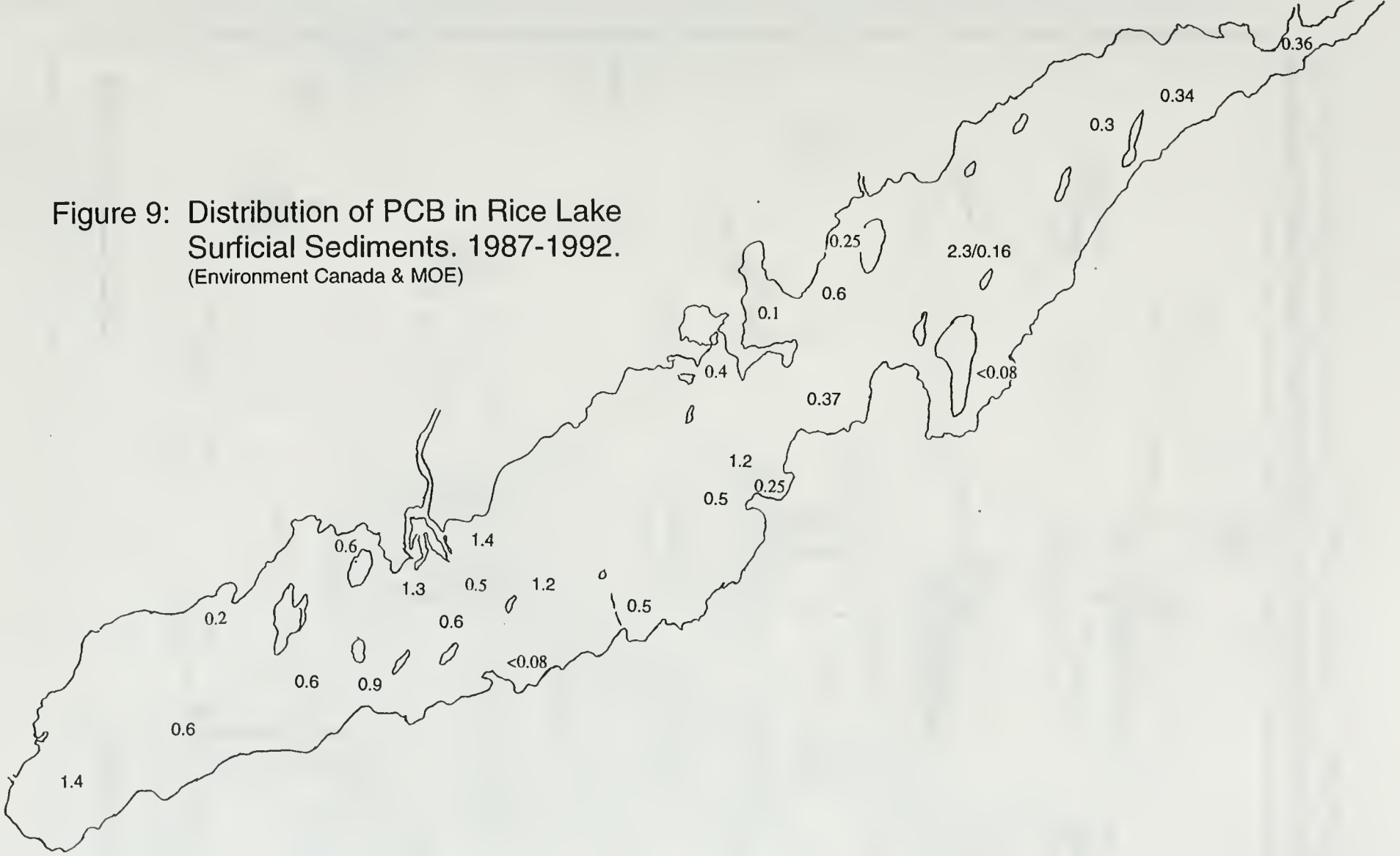


Figure 10: Station Locations for 1996 In-situ Mussel Biomonitoring

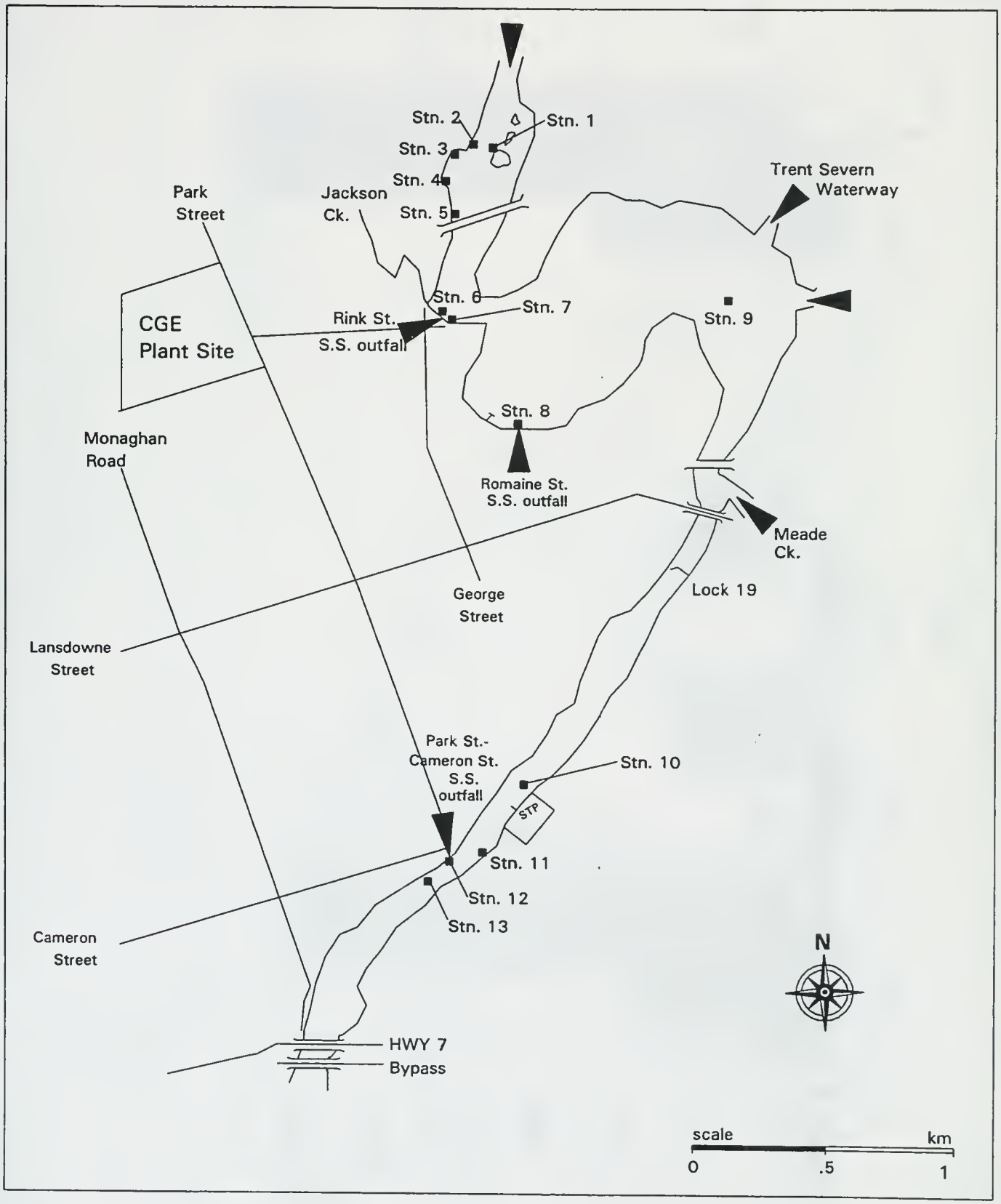


Figure 11: Historical Levels of PCBs in Mussel Tissue Exposed in the Otonabee River near Peterborough (1985 - 1996)

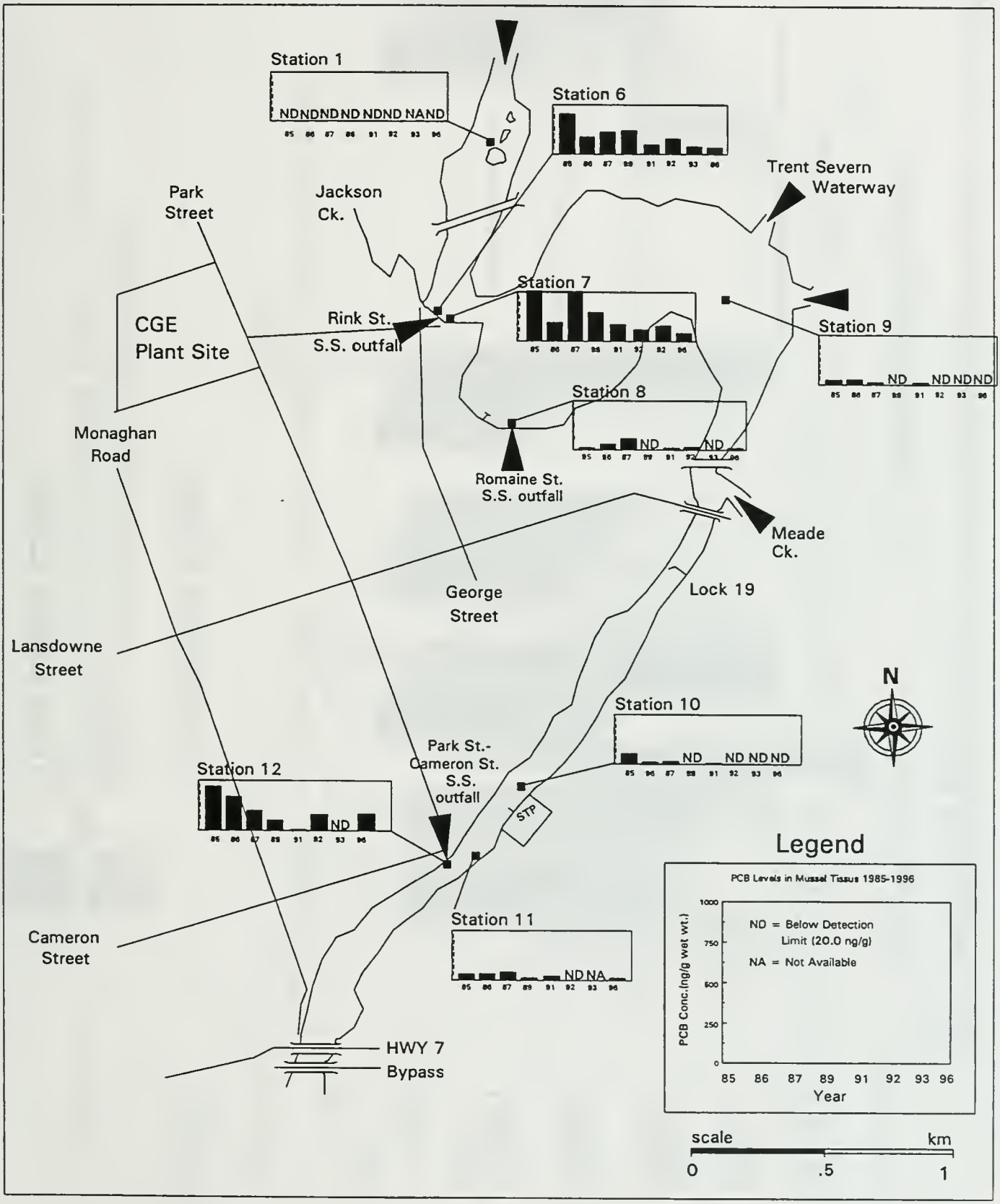


Figure 12: PCBs (ng/g) in 65 cm Carp - Rice Lake/Otonabee River 1984-1996

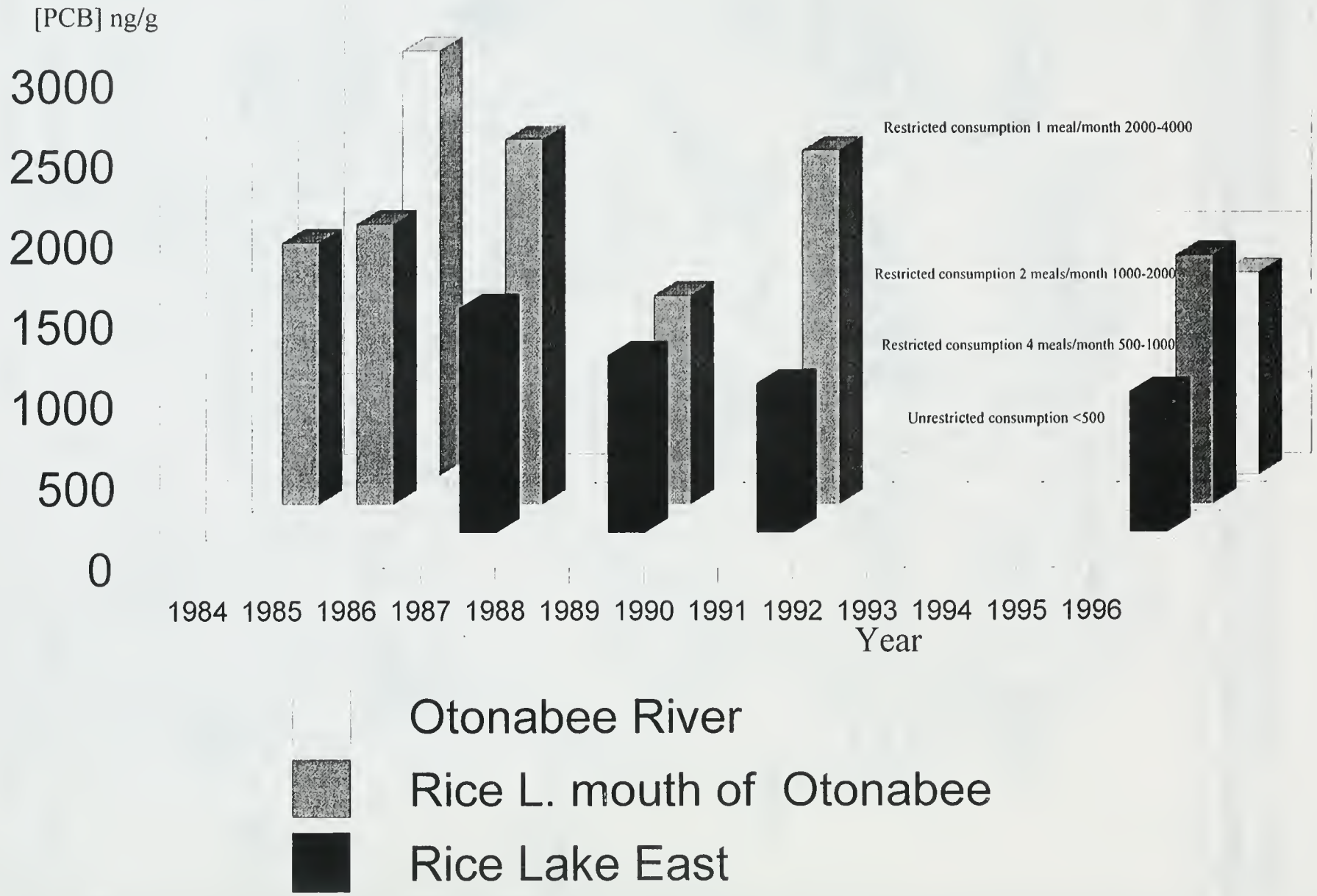


Figure 13: Rice Lake at mouth of Otonabee River 1984-1996

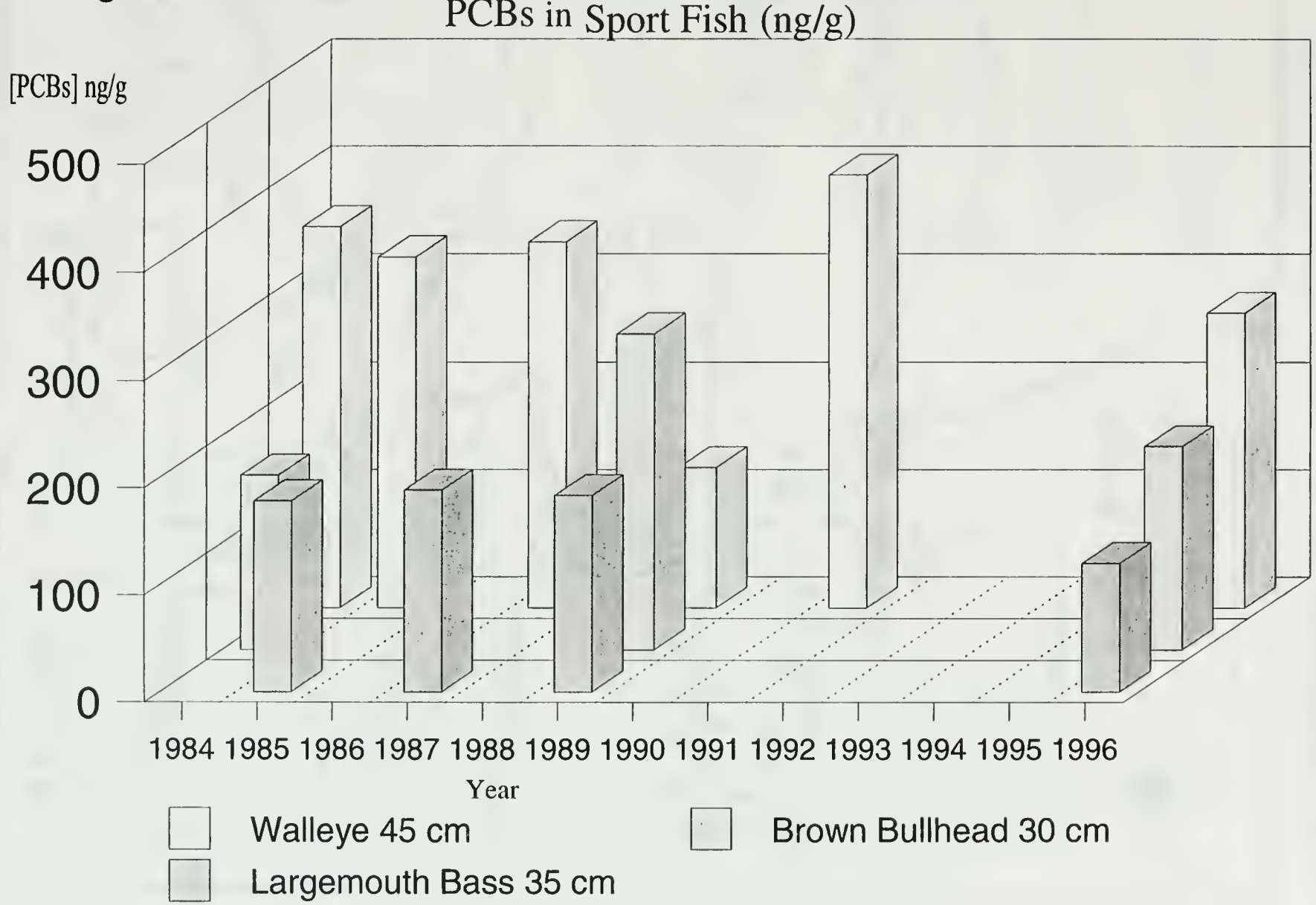


Fig. 14: Total PCB residues (ng/g) in young-of-the-year yellow perch from the Otonabee River, Rice Lake and Seymour Lake from 1977 to 1996. Values are means +/- 95% confidence limits.

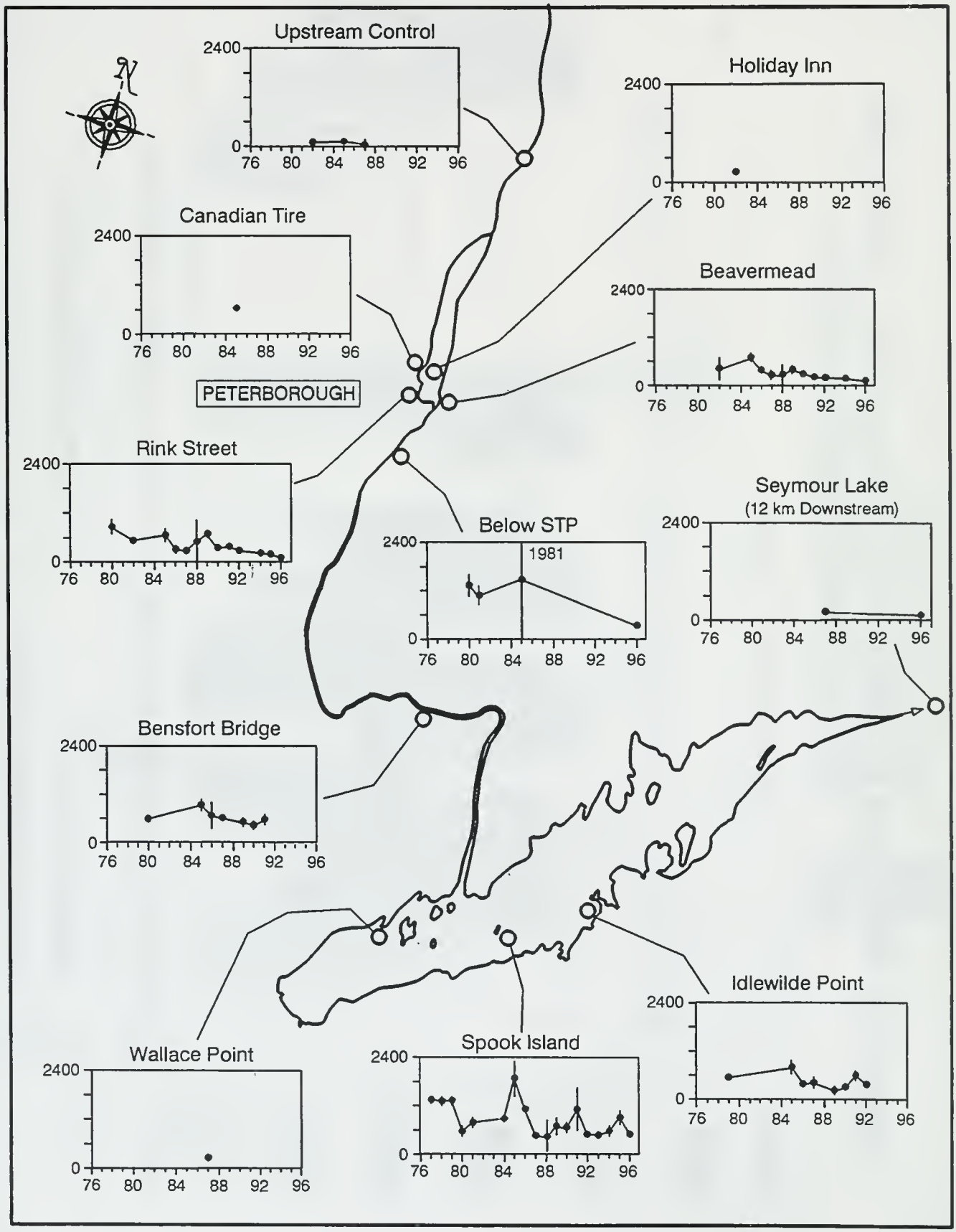
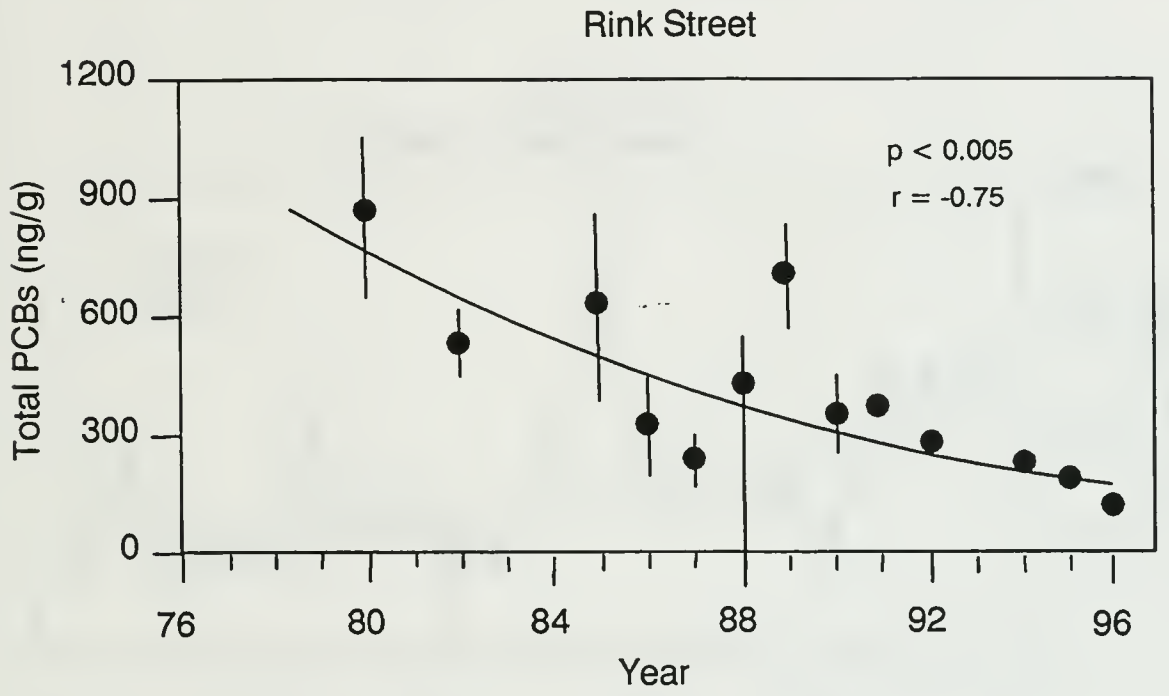


Figure 15: Total PCB residues (ng/g) in young-of-the-year yellow perch in the Otonabee River at Rink Street and Beavermead in Little Lake. Values are means ± 95% confidence limits.



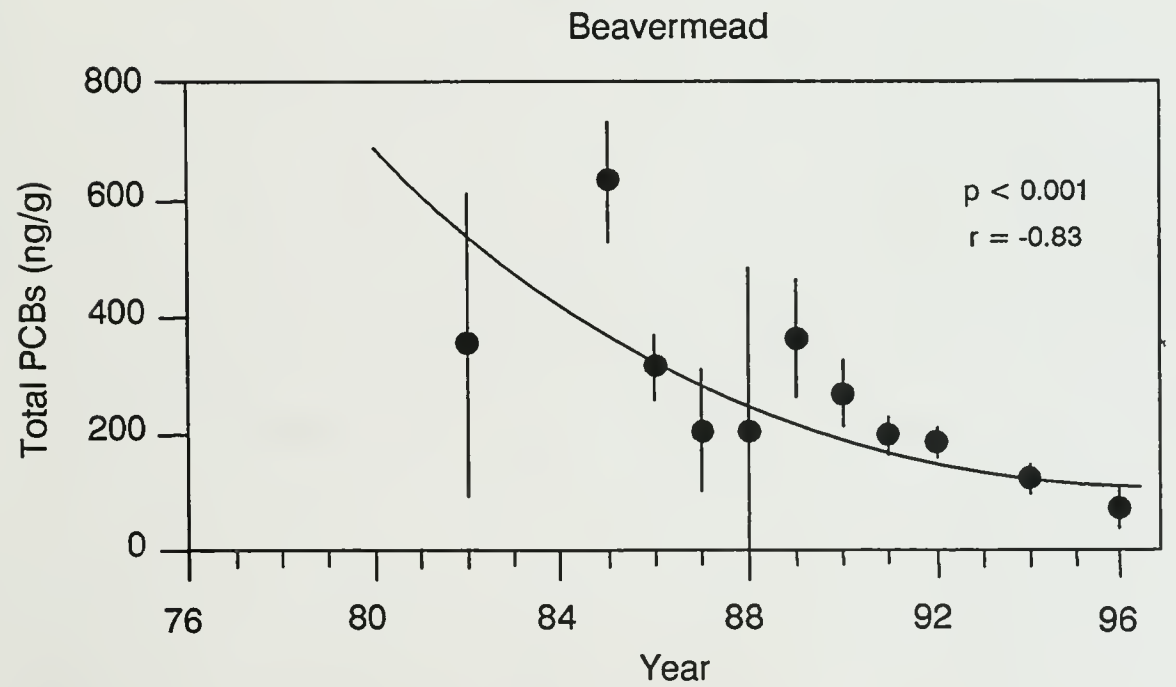
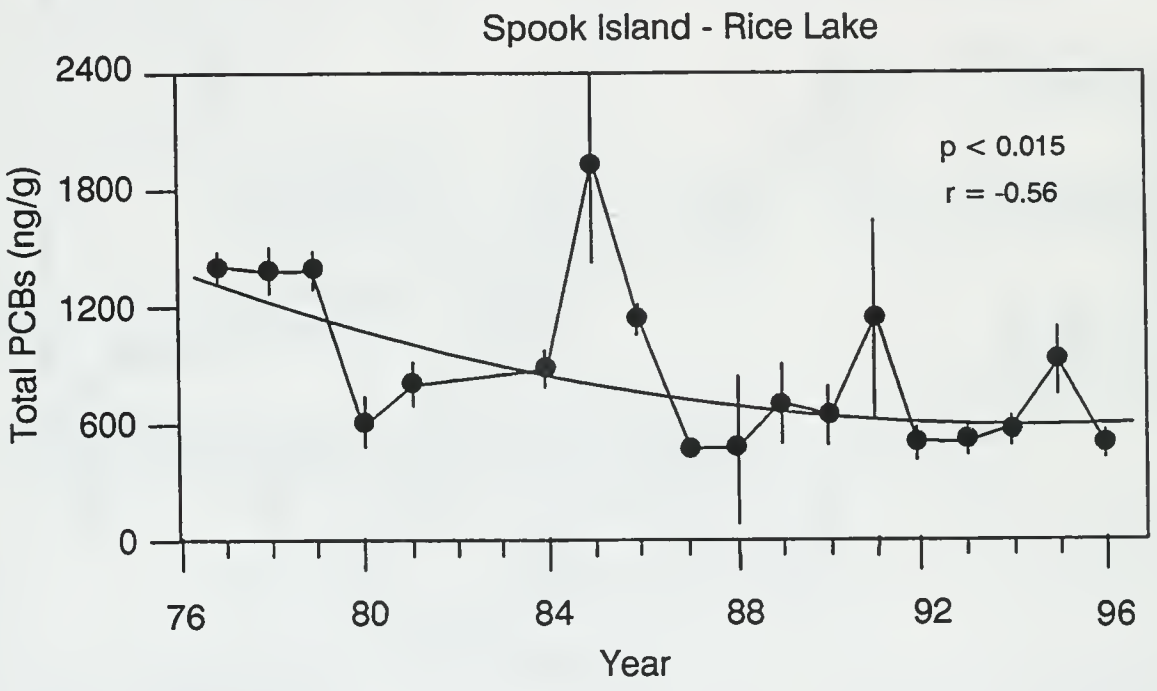


Figure 16: Total PCB residues (ng/g) in yellow perch in Rice Lake at Spook Island. Values are means ± 95% confidence limits.



Tables

Table 1: Sediment Sampling Locations in Little Lake and Otonabee River. 1996.

Station	Location	Sample Type	Chemical Tests	Description
T1-1	Little Lake. ~20m east of public dock. Map Ref: 10 17 71410 490773 (44°17'36"N, 78°18'59"W)	Ponar Grab (8 cm deep)	TOC PCB/oc PAH	Very loose silt. Light brown to dark brown in colour. Some wood chips.
T2-1	Little Lake. ~10m east of small dock in line with fireworks platform. Map Ref:10 17 71407 490789 (44°17'41"N, 78°19'00"W)	Ponar grab (~8 cm deep).	TOC PCB/oc PAH	Very loose silt. Brown surface layers and black deeper layers. A few small oil blobs in sediment.
T2-2	Little Lake. ~5m to east of fireworks platform. Map Ref: 10 17 71432 490790 (44°17'41"N, 78°18'49"W)	Ponar grab (~8 cm deep).	TOC PCB/oc PAH	Very loose silt. Brown to black with fine organic detritus. Some wood waste in deeper layers.
T3-1	Little Lake. Along transect 3 (Gov/t dock to launch ramp in Beavermead park) off Trent Canal. Map Ref: 10 17 71487 490812 (44°17'47"N, 78°18'25"W)	Ponar grab (~8 cm deep)	TOC PCB/oc PAH	Loose sandy silt. Light brown in colour.
T3-2	Little Lake. Along transect 3 in line with red marker and e. end of bridge. Map Ref: 10 17 71500 490814 (44°17"47"N, 78°18'19"W)	Ponar grab (~6 cm deep)	TOC PCB/oc PAH	Loose silty sand. Light brown in colour.
T4-1	Little Lake. Map Ref: 10 17 71454 490836 (44°17'55"N, 78°18'39"W)	Ponar grab (~7 cm deep)	TOC PCB/oc PAH	Very loose silt with fine organic detritus. Light brown in colour.
T4-2	Little Lake. Map Ref: 10 17 71454 490836 (44°17'55"N, 78°18'27"W)	Ponar grab (8-9 cm deep)	TOC PCB/oc PAH	Loose brown silt overlying deeper layer of brown-grey/black silt.
OR-1	Otonabee R. ~ 2 mi downstream of Hwy 7 on w. side at mouth of embayment. Map Ref: 10 17 71236 490362 (44°15'24"N, 78°20'24'W)	Cores (6.25 cm diam.): 30-40 cm. 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc PAH	Top layer fine black silt and organic detritus. Wood chips in bottom layer. ~50% compression.

OR-2	Otonabee R. ~ 1.2 km downstream of Telephone Pt., at mouth of embayment on e. side. Map Ref: 10 17 71269 490207 (44°14'34"N, 78°20'08"W)	Cores (6.25 cm diam.): 37 cm 3 sections: 0-10; 10-20; 20-30 cm.	TOC PCB/oc	Top layer fine black silt and organic detritus. Wood chips in bottom layer. No clay layer encountered. ~50% compression.
OR-3	Otonabee R. at mouth of embayment on w. side ~1.2 km upstream of Cavan Creek. Map Ref: 10 17 71190 490037 (44°13'40"N, 78°20'49"W)	Cores (6.25 cm diam.): 31; 35; 44 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser silt and sand with a little wood waste in bottom layer. ~50% compression.
OR-4	Otonabee R. on w. side ~ 1.2 km downstream of Cavan Ck at mouth of small embayment. Map Ref: 10 17 71124 489843 (44°12'38"N, 78°21'16"W)	Cores (6.25 cm diam.): 50; 45; 40 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer of silt and wood waste. Clay layer at 30 cm. ~50% compression.
OR-5	Otonabee R. on w. side just upstream of bridge at Wallace Pt. at mouth of embayment. Map Ref: 10 17 71286 489571. (44°11'53"N, 78°20'09"W)	Cores (6.25 cm diam.): 40; 40; 35 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer of silt and lots of wood waste. Clay layer not encountered. ~50% compression.
OR-6	Otonabee R. on n. side ~ 3 km downstream of Wallace Pt. Map Ref: 10 17 71471 489736. (44°11'59"N, 78°18'47"W)	Cores (6.25 cm diam.): 50; 45; 55 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer of silt and lots of wood waste. Clay layer encountered ~ 35 cm down. ~50% compression.
OR-7	Otonabee R on n. side at mouth of marsh ~ 1.2 km don from Bensfort Bridge. Map Ref: 10 17 71808 489840. (44°12'29"N, 78°16'13"W)	Cores (6.25 cm diam): 30 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer of silt and wood waste. Clay layer encountered ~ 15 cm down in two of the cores. ~50% compression.
OR-8	Otonabee R., on s. side ~ 1 km upstream of Campbelltown public dock. Map Ref: 10 17 72035 489942. (44°12'59"N, 78°14'29"W)	Cores (6.25 cm diam): 39 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer of silt and some wood waste. Hard clay layer encountered ~ 35 cm down. ~50% compression.

OR-9	Otonabee R. on e. side ~1.2 km downstream of Kent Creek. Map Ref: 10 17 72069 489584. (44°11'03"N, 78°14'24"W)	Cores (6.25 cm diam): 30; 30; 20 cm 3 sections: 0-10; 10-20; 20-30 (comp of 2) cm.	TOC PCB/oc	Top layer fine black silt and organic detritus overlying denser layer fibrous reddish peaty material (below 15 cm). Clay layer not encountered. ~50% compression.
OR-10	At mouth, in Rice Lake. Map Ref: 10 17 72150 489252. (44°09'15"N, 78°13'48"W)	Cores (6.25 cm diam): 20; 20; 38 cm 3 sections: 0-10; 10-20; 20-30 cm	TOC PCB/oc	Dark layer of fine silt mixed with wood chips in top 20 cm. Red peat layer below 20 cm. ~ 50% compression.
RS-1	At Rink St sewer outfall. Map Ref: 10 17 71490 490803 (44°17'45"N, 78°19'05"W)	Ponar Grab ~8 cm	TOC PCB/oc PAH	Black sand/gravel/silt mix. Oily smell.

Table 2: PCB and Organochlorine Pesticide Concentrations in Sediment. Little Lake and Otonabee River 1996. All values in ng/g dry weight unless indicated otherwise.

Station	Depth cm	PCB, total	Heptachlor	Aldrin	pp-DDE	Mirex	α-BHC	β-BHC	γ-BHC	α-Chlor-dane	γ-Chlor-dane	Oxychlor-dane
Little Lake												
RS-1		1300 PS1	1<W	1<W	1<W	1<W	1<W	3<T	1<W	2<W	2<W	2<W
T1-1		960 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T2-1		520 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T2-2		460 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T3-1		180 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T3-2		20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T4-1		860 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
T4-2		400 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Otonabee River												
Stn 1	0-10 cm	1000 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	720 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	80 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 2	0-10 cm	560 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	2400 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	200 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 3	0-10 cm	160 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	2300 PS1	1<W	1<W	1<W	5<W	1<W	1<W	6<T	2<W	2<W	2<W
	20-30 cm	680 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 4	0-10 cm	440 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	4<T	2<W
	10-20 cm	980 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	12<T	2<W
	20-30 cm	260 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 5	0-10 cm	100 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	4<T	2<W
	20-30 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 6	0-10 cm	760 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	1600 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	6<T	2<W
Stn 7	0-10 cm	1300 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	320 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 8	0-10 cm	440 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	620 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	80 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 9	0-10 cm	380 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	60 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
Stn 10	0-10 cm	360 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	10-20 cm	680 PS1	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W
	20-30 cm	20<W	1<W	1<W	1<W	5<W	1<W	1<W	1<W	2<W	2<W	2<W

Table 2: cont'd.

Station	Depth	op-DDT	pp-DDD	pp-DDT	Methoxy chlor	Heptachlor epoxide	Endo-sulfan I	Dieldrin	Endrin	Endo-sulfan II	Endo sulphan sulfonate	TOCmg/g
Little Lake												
RS-1		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	65
T1-1		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	92
T2-1		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	45
T2-2		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	90
T3-1		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	50
T3-2		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	5.1
T4-1		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	76
T4-2		5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	91
Otonabee River												
Stn 1	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	66
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	83
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	70
Stn 2	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	40
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	61
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	88
Stn 3	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	32
	10-20cm	5<W	5<W	5<W	5<W	1<W	8<T	8<T	4<W	4<W	4<W	41
	20-30cm	5<W	5<W	5<W	5<W	1<W	4<T	2<W	4<W	4<W	4<W	64
Stn 4	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	56
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	65
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	110
Stn 5	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	150
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	120
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	130
Stn 6	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	76
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	130
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	110
Stn 7	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	130
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	130
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	55
Stn 8	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	60
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	110
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	91
Stn 9	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	120
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	140
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	110
Stn 10	0-10cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	64
	10-20cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	56
	20-30cm	5<W	5<W	5<W	5<W	1<W	2<W	2<W	4<W	4<W	4<W	74

PS1 = PCB resembled a mixture of Aroclors 1248, 1254 and 1260 <W - below detection limit <T- trace amount

Table 3: PAH Concentrations in Sediment Samples. Little Lake and Otonabee River. 1996. All concentrations ng/g (ppb) dry weight.

Station	Depth	Naphth-alene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluoran-thene	Pyrene	Benzo[a] anthracene
Little Lake										
RS-1	Surface	1900	40<T	2900	5600	28000	6200	31000	24000	11000
T1-1	Surface	60<T	40<T	60<T	80<T	1000	220	2400	2100	920
T2-1	Surface	20<W	20<W	40<T	60<T	580	120	1100	940	440
T2-2	Surface	60<T	20<W	20<W	20<W	380	80<T	980	860	400
T3-1	Surface	60<T	40<T	60<T	60<T	820	200	1800	1500	780
T3-2	Surface	20<W	20<W	20<W	20<W	40<T	20<W	60<T	60<T	20<W
T4-1	Surface	80<T	40<T	60<T	120	860	220	1600	1400	700
T4-2	Surface	60<T	100	60<T	80<T	920	180	1900	1600	860
Otonabee River										
OR1	0-10cm	40<T	80<T	20<W	40<T	420	120	1100	1100	720
OR1	10-20cm	60<T	60<T	20<W	40<T	440	160	1300	1600	940
OR1	20-30cm	60<T	40<T	20<W	40<T	240	80<T	640	920	540
PSQG-LEL		n.a	n.a.	n.a.	190	560	220	750	490	320
PSQG-SEL		n.a.	n.a.	n.a.	160000	950000	370000	1020000	850000	1480000

Station	Depth	Chrysene	Benzo[b] fluoran-thene	Benzo[k] fluoran-thene	Benzo[a] pyrene	Benzo [g,h,i] perylene	Dibenzo [a,h]an-thracene	Indeno [123-cd] pyrene	Total PAH	TOC mg/g
Little Lake										
RS-1	Surface	10000	11000	6500	9500	11000	1400	5500	165500	65
T1-1	Surface	1200	1600	600	960	160<T	1100	760	12500	92
T2-1	Surface	520	740	240	400	80<T	440	320	5740	45
T2-2	Surface	520	740	240	400	80<T	480	360	5280	90
T3-1	Surface	760	1000	360	680	120<T	600	440	8840	50
T3-2	Surface	20<W	40<T	20<W	40<W	40<W	40<W	40<W	480	5.1
T4-1	Surface	720	1000	360	680	120<T	600	440	8560	76
T4-2	Surface	940	1500	500	1000	200	1000	680	10900	91
Otonabee River										
OR1	0-10cm	740	1000	340	720	160<T	680	480	7280	66
OR1	10-20cm	980	1200	400	840	160<T	760	560	8960	83
OR1	20-30cm	620	640	200	480	80<T	360	280	4960	70
PSQG-LEL		340	n.a.	240	370	170	60	200	4000	
PSQG-SEL*		480000	n.a.	1340000	1440000	320000	130000	320000	10000000	

* SEL values are expressed on an organic carbon basis (ng/g organic carbon). These are converted to a bulk sediment concentration based on actual TOC concentrations in the sediment at the individual sampling locations.

TABLE 4. Mean (± s.d.) water quality characteristics in Otonabee River 1996 sediment bioassays.

Test Organism: Mayfly (Hexagenia limbata)[a]			Test Temperature: 18.5°C (0.8)		
Station	*pH*	*D.O.* mg/L	*Conductivity* umho/cm	*Total Ammonia* mg/L	*Un-ionized Ammonia* mg/L
Control	7.92 (.04)	9.0 (0.2)	300 (6)	0.10 (0.01)	0.003
Stn OR-1	8.00 (.13)	8.9 (0.2)	369 (13)	1.26 (1.04)	0.047
Stn OR-6	8.01 (.13)	9.0 (0.1)	383 (26)	1.36 (1.10)	0.051
Stn OR-7	8.01 (.07)	8.8 (0.2)	373 (38)	0.69 (0.72)	0.026
Stn RS-1	8.13 (.15)	8.9 (0.1)	428 (31)	2.03 (1.95)	0.125
Test Organism: Midge (Chironomus tentans)[b]			Test Temperature: 21.5°C (0.5)		
Station	*pH*	*D.O.* mg/L	*Conductivity* umho/cm	*Total Ammonia* mg/L	*Un-ionized Ammonia* mg/L
Control	7.79 (.08)	8.3 (0.2)	318 (9)	0.12 (0.02)	0.004
Stn OR-1	7.99 (.06)	8.2 (0.2)	382 (12)	2.30 (1.94)	0.097
Stn OR-6	7.96 (.12)	8.1 (0.4)	394 (12)	2.93 (2.49)	0.121
Stn OR-7	7.96 (.01)	8.2 (0.2)	381 (12)	1.60 (1.30)	0.067
Stn RS-1	7.92 (.26)	7.7 (0.9)	437 (16)	5.00 (2.27)	0.184
Test Organism: Minnow (Pimephales promelas)[a]			Test Temperature: 21.3°C (0.6)		
Station	*pH*	*D.O.* mg/L	*Conductivity* umho/cm	*Total Ammonia* mg/L	*Un-ionized Ammonia* mg/L
Control	7.39 (.30)	7.7 (0.5)	314 (19)	0.54 (0.57)	0.010
Stn OR-1	7.61 (.20)	7.2 (0.7)	399 (57)	9.50 (5.32)	0.227
Stn OR-6	7.68 (.11)	6.9 (1.2)	417 (40)	9.00 (7.32)	0.146
Stn OR-7	7.70 (.18)	7.7 (0.3)	391 (38)	5.78 (4.74)	0.189
Stn RS-1	7.85 (.10)	7.8 (0.1)	510 (85)	7.77 (6.95)	0.272

a Sample size N=4; b Sample size N=3;
Underlining indicates un-ionized ammonia concentrations that exceed the PWQO of 0.02 mg/L

TABLE 5. Sediment physical and nutrient characteristics in control and Otonabee River 1996 sediment used in sediment bioassays.

Station	*% Sand* (2mm-62um)	*% Silt* (62-3.7um)	*% Clay* (3.7-0.1um)	*% LOI*	*TOC* mg/g	*TP* mg/g	*TKN* mg/g
Georgian Bay Control	4.0	70.6	25.7	5.3	22	0.9	1.9
Otonabee River Station OR-1	29.0	57.7	12.6	22.0	130	1.4	9.4
Otonabee River Station OR-6	42.0	46.2	12.3	6.2	34	1.4	3.4
Otonabee River Station OR-7	27.0	57.7	15.0	5.8	31	1.2	3.1
Little Lake Station RS-1	58.0	31.7	10.2	7.2	47	0.8	2.4
PSQG SEL Conc (mg/g dry weight)					100	2.0	4.8

Shading indicate sediment nutrient concentrations that exceed PSQG-SELs.

TABLE 6. Bulk concentrations of trace metals in control and Otonabee River 1996 sediment (µg/g dry weight) used in sediment bioassays.

Station	*Al %*	*As*	*Cd*	*Cr*	*Cu*	*Fe %*	*Hg*	*Mn*	*Ni*	*Pb*	*Zn*
Georgian Bay Control	1.4	4.1	0.3 <T	29	15	2.5	0.06	690	21	58	89
Otonabee River Station OR-1	1.0	2.5	2.7	37	78	1.8	0.34	500	17	100	210
Otonabee River Station OR-6	0.6	1.0	0.7 <T	17	19	1.2	0.09	380	10	27	84
Otonabee River Station OR-7	0.8	1.0	0.5 <T	16	13	1.2	0.08	490	7	21	66
Little Lake Station RS-1	0.4	1.4	0.9 <T	25	84	1.2	0.11	310	9	90	180
PSQG SEL Conc.	NA	33	10	110	110	4.0	2.0	1100	75	250	820
PSQG LEL Conc.	NA	6.0	0.6	26	16	2.0	0.20	460	16	31	120

<T - Trace Amount; Shading indicate sediment trace metal concentrations that exceed PSQG-SELs.

Underlining indicate sediment trace metal concentrations that exceed PSQG-LELs; NA - Not Available.

TABLE 7. Bulk sediment concentrations for chlorinated organics and pesticides in Otonabee River 1996 sediment (ng/g, dry weight) used in bioassays.

All Stations (exceptions listed below)	Heptachlor	1 <W
	Aldrin	1 <W
	Mirex	5 <W
	a-BHC	1 <W
	b-BHC	1 <W
	g-BHC	1 <W
	a-Chlordane	2 <W
	g-Chlordane	2 <W
	Oxychlordane	2 <W
	op-DDT	5 <W
	pp-DDD	5 <W
	pp-DDT	5 <W
	pp-DDE	1 <W
	Methoxychlor	5 <W
	Heptachlor epoxide	1 <W
	Endosulphan I	2 <W
	Dieldrin	2 <W
	Endrin	4 <W
	Endosulphan II	4 <W
	Endosulphan sulphate	4 <W
	Hexachlorobutadiene	1 <W
	Octachlorostyrene	1 <W
	Hexachlorobenzene	1 <W
	123-Trichlorobenzene	2 <W
	124-Trichlorobenzene	2 <W
	135-Trichlorobenzene	2 <W
	1234-Tetrachlorobenzene	1 <W
	1235-Tetrachlorobenzene	1 <W
	1245-Tetrachlorobenzene	1 <W
	Hexachloroethane	1 <W
	Pentachlorobenzene	1 <W
	236-Trichlorotoluene	1 <W
	245-Trichlorotoluene	1 <W
Station RS-1	g-BHC	3 <T
Station OR-1	Total PCBs	1200
Station OR-6		80
Station OR-7		60
Station RS-1		1400

<W - Not Detected; <T - Trace Amount.

Underlining indicate sediment PCB concentrations that exceed PSQG-LELs.

TABLE 8. Bulk concentrations of polycyclic aromatic hydrocarbons in Otonabee River 1996 sediment used in sediment bioassays (ng/g, dry weight).

Parameter	Station OR - 1	Station OR - 6	Station OR - 7	Station RS - 1
Acenaphthene	40 <T	20 <W	20 <W	960
Acenaphythylene	60 <T	20 <W	20 <W	40 <T
Anthracene	80 <T	20 <W	20 <W	1800
Benzo[a]anthracene	1200	260	140	8200
Benzo[b]fluoranthene	1400	300	180	7500
Benzo[k]fluoranthene	1000	240	140	4100
Benzo[ghi]perylene	720	160 <T	120 <T	3300
Benzo[a]pyrene	880	160 <T	80 <T	4200
Chrysene	1300	300	200	7400
Dibenzo[ah]anthracene	240	40 <W	40 <W	1200
Fluoranthene	1700	440	260	19000
Fluorene	40 <T	20 <W	40 <T	2400
Indeno[123-cd]pyrene	1100	240	160 <T	5400
Naphthalene	40 <T	20 <W	20 <W	1300
Phenanthrene	640	140	100	15000
Pyrene	1400	340	220	13000
Total PAHs	11840	2650	1700	94800

<W - Not Detected; T - Trace Amount Measured.
Underlining indicate sediment PAH concentrations that exceed PSQG-LELs.
PSQG's not available for acenapthene, acenaphthylene, benzo[b]fluorene and naphthalene.
One-half the detection limit value was used to calculate the total PAH sediment concentration.

TABLE 9. Summary of biological results on mayfly, midge and minnow sediment bioassays for control and Otonabee River 1996 sediments.

Mean values (± standard deviation) where sample size n=3 reps for minnow and n=4 reps for mayfly and midge tests.

Test Organism	*Hexagenia limbata* (Mayfly)		*Chironomus tentans* (Midge)		*Pimephales promelas* (Fathead Minnow)
Station	*% Mortality*	*Ave. Individual Body Weight* (mg wet wt.)	*% Mortality*	*Ave. Individual Body Weight* (mg wet wt.)	*% Mortality*
Honey Harbour Control	A 5.0 (6)	C 5.55 (0.7)	A 3.3 (4)	AB 16.09 (0.6)	A 0 (0)
Otonabee River Station OR-1	A 0 (0)	A 23.29 (2.0)	A 0 (0)	AB 15.42 (0.2)	A 0 (0)
Otonabee River Station OR-6	A 0 (0)	A 21.56 (0.8)	A 8.2 (3)	AB 15.63 (1.8)	A 0 (0)
Otonabee River Station OR-7	A 2.5 (5)	A 24.84 (3.1)	A 14.9 (11)	B 14.74 (1.2)	A 3.3 (6)
Little Lake Station RS-1	A 2.5 (5)	B 14.90 (1.4)	A 3.3 (4)	A 16.72 (1.2)	A 10.0 (10)
% MSD	9.5	-	25.5	-	14.4
% C.V.	200	8.7	69.6	7.1	118
D.P.	1.0	5.3	3.2	1.7	2.5

* %Mortality value is significantly different than the control sediment (Dunnett's 1-tailed t-test;$p<0.05$).

A Means sharing a common letter within a column are not significantly different; Tukey's HSD test for % Mortality ($p<0.05$) and planned comparisons using LSMEANS for comparing Body Weight ($p<0.01$).

MSD - Minimum Significant Difference; C.V. - Coefficient of Variation; D.P. - Discriminatory Power.

TABLE 10. Total polychlorinated bipyhenyl concentrations in fathead minnows exposed to control and Otonabee River 1996 sediments in the laboratory and associated biota-sediment accumulation factors.

Station	Control Honey Harbour	Otonabee River Stn OR-1	Otonabee River Stn OR-6	Otonabee River Stn OR-7	Little Lake Stn RS-1
Sediment PCB (ng/g dry weight)	NA	1200	80	60	1400
Minnow PCB (ng/g wet weight)	20 <W	380	100	60	560
	20 <W	600	100	100	520
Average ± s.d.	20 (0) <W	490 (155)	100 (0)	80 (28)	540 (28)
BSAF (tissue/sediment dry wt)		2.6	8.2	8.8	2.5
BSAF (corrected) (tissue lipid/sediment OC)		29.1	16.5	17.0	8.5
BSAF (revised) (tissue lipid 5%)		7.0	5.6	5.4	2.3

<W - Not Detected; <T - Trace Amount Measured; NA - Not Analyzed; One-half the detection limit was used to calculate BSAFs.

TABLE 11. Spatial variability in sediment toxicity and sediment quality for Otonabee River 1996 samples.

Station	Sediment Quality	Sediment Total PCBs (ng/g dry wt)	Minnow Total PCBs (ng/g wet wt)	Mayfly Mortality	Mayfly Ave wt	Midge Mortality	Midge Ave wt	Minnow Mortality
Otonabee River Stn OR-7	High	60	80	N	N	N	N	N
Otonabee River Stn OR-6	High	80	100	N	N	N	N	N
Little Lake Stn RS-1	Slight	1400	540	N	T	N	N	N
Otonabee River Stn OR-1	Moderate	1200	490	N	N	N	N	N

N - Not Toxic, % mortality less than control criteria or $p>0.05$ and $p>0.10$ for growth data;
T - Toxic, % mortality greater than control criteria or $p<0.05$ and $p<0.10$ for growth data.

TABLE 12. Spearman rank correlation coefficients indicating significant positive (direct) and negative (inverse) correlations among toxicity data for Otonabee River 1996 sediments.

	Mayfly Survival	Mayfly Growth	Midge Survival	Midge Growth
Mayfly Growth	n.s.			
Midge Survival	n.s.	n.s.		
Midge Growth	n.s.	- 1.00 **	n.s.	
Minnow Survival	+ .942 *	n.s.	n.s.	n.s.

** $p < 0.05$; * $p < 0.10$; n.s. - Not Significant at $p>0.10$.

TABLE 13. Spearman rank correlation analysis summary indicating significant negative (inverse) or positive (direct) correlation between biological endpoints and sediment physical and chemical parameters for Otonabee River 1996 samples.

Toxicity Endpoint	Mayfly Survival	Mayfly Growth	Midge Survival	Midge Growth	Minnow Survival
Bulk Concentration		- %Sand **	+ TOC ** + Arsenic * + Cadmium ** + Chromium ** + Mercury ** + Lead ** + Zinc **	+ %Sand **	
TOC corrected [a] Concentration	+ Mercury *	- Lead **		+ Lead **	+ Mercury *

a Included As, Cd, Cr, Cu, Hg, Pb and Zn.

** $p < 0.01$; * $p < 0.10$.

Table 14: Peterborough Mussel Biomonitoring Study 1996			
Stn. #	Location	# recovered	Observations
1	Upstream Control	15	
2	West Bank Opposite control	14	1 dead
3	Top of small bay on west side of river	14	1 dead
4	Bottom of small bay on west side	15	
5	Above railway bridge on west side	15	
6	Rink street upstream	15	
7	Rink street downstream	15	
8	Off Romaine St. sewer outfall	15	
9	Little Lake - marker buoy near cemetary	15	
10	Otonabee River Above STP	15	
11	Otonabee River Below STP	15	
12	Park/Cameron sewer outfall	8	1 cage missing low flow
13	10 m downstream of Park/Cameron outfall	15	

Table 15: Multiple range analysis for PCB Tissue Levels in Exposed Mussels (Tukey HSD)

Stn #	Reps	Mean PCB conc. (ng/g)	Homogeneous Groups
1	3	ND	
2	3	ND	
4	3	ND	
5	3	ND	
9	3	ND	
10	3	ND	
8	3	20.0	
3	3	40.0	
11	3	40.0	
13	3	40.0	
6	3	120.0	
7	3	153.3	
12	3	266.7	

ND - not detected

* Stations aligned vertically are not significantly different

Table 16 : Sport fish collected from the Otonabee River/Rice Lake System 1996-7		
Location	Sample date	Species (number collected)
Otonabee above Trent University	Aug 28/96	Carp (1) Walleye (1) Brown Bullhead (3) Smallmouth Bass (7) Yellow Perch (10) Black Crappie (4) Rock Bass (4) Pumpkinseed (5) Bluegill (10)
Otonabee above Trent University	June 16/97	Walleye (6) Brown Bullhead (5)
Little Lake, Peterborough	Aug 28/96	Carp (1) Smallmouth Bass (3) Brown Bullhead (10) Walleye (9) Yellow perch (10) Black Crappie (10) Pumpkinseed (10) Rock Bass (10) Bluegill (3)
Otonabee at Bensfort Bridge	Sept 10/96	Carp (6) Brown Bullhead (10) Black Crappie (10) Yellow Perch (9) Pumpkinseed (8) Largemouth bass (3) Walleye (8) Rock Bass (10) Smallmouth Bass (10)
Rice Lake at mouth of Otonabee River	Sept 10/96	Carp (5) Brown Bullhead (10) Black Crappie (7) Yellow Perch (10) Pumpkinseed (6) Largemouth Bass (10) Walleye (10)
Rice Lake east end at Serpent Mounds	June 5/97	Carp (10) Walleye (14) Largemouth Bass (10) Smallmouth Bass (1) Brown Bullhead (12) Pumpkinseed (11) Yellow Perch (8) Bluegill (9) Black Crappie (13)

Table 17: PCB Concentration in Sport Fish 1996-97				
Location	**Species**	**Sample Type**	**#**	**Results**
Otonabee River upstream of Trent University	Carp	I	1	40 ng/g
	Walleye	C	5	Pending
	Smallmouth Bass	C	5	ND
	Brown Bullhead	C	3	ND
Otonabee River at Little Lake	Carp	I	1	240 ng/g
	Walleye	I	9	Pending
	Smallmouth Bass	I	3	X=53.3 R=40-80 ng/g
Otonabee River at Bensfort Bridge	Carp	I	6	X=797 StdX=1255 R=180-2500 ng/g
	Walleye	I	8	Pending
	Brown Bullhead	I	10	X=108 R=40-160 ng/g
	Smallmouth Bass	C	5	200 ng/g
	Largemouth Bass	I	3	X=87 R=60-120 ng/g
	Black Crappie	C	5	ND
Rice Lake at mouth of Otonabee River	Carp	I	5	X=1800 StdX=1539 R=100-2700ng/g
	Walleye	I	10	X=312 Std X= 274 R=140-1000 ng/g
	Brown Bullhead	I	10	X=198 Std X=190 R=40-500 ng/g
	Pumpkinseed	C	5	40 ng/g
	Black Crappie	C	5	40 ng/g
	Yellow Perch	C	5	80 ng/g
	Largemouth Bass	C	5	120 ng/g
Rice Lake east end at Serpent Mounds	Carp	I	10	Analysis pending for all species
	Walleye	I	14	
	Brown Bullhead	I	5	
	Largemouth Bass	C	5	

I-Individual fish
C-Composite
X-Mean concentration
Std X-Concentration of PCBs in standard length fish
Carp - 65 cm
Walleye - 45 cm
Brown Bullhead - 30 cm

Table 18: Total PCB residues in young-of-the-year yellow perch from the Otonabee River, Rice Lake and Seymour Lake from 1977 to 1997. Values are means ± standard deviation. (Spottail shiners (SS) were collected for comparison in 1996 and 1997).

STATION	YEAR	n	FISH LENGTH (mm)	LIPID (%)	PCB (ng/g)
OTONABEE RIVER					
Lakefield	1993	5	64-1	1.5-0.2	ND
Control	1982	3	100-5	5.1-0.5	76-12
	1985	5	69-5	2.2-0.7	90-28
	1987	2	51-2	1.5-0.3	20-14
Holiday Inn (east shore)	1982	4	77-4	4.4-0.6	224-31
Canadian Tire (west shore)	1985	4	68-4	2.7-1.1	620-35
	SS 1996	2	55-0	2.4-0.5	80-0
Rink Street	1980	6	89-5	4.5-0.4	865-149
	1982	4	72-3	4.2-0.4	524- 40
	1985	5	71-2	2.6-0.8	657-146
	1986	5	64-5	2.3-0.2	312- 67
	1987	6	52-5	1.7-0.3	244- 36
	1988	4	68-2	2.8-0.2	440-270
	1989	5	64-2	3.3-0.4	700-84
	1990	6	63-2	2.4-0.4	346-62
	1991	5	64-2	2.1-0.1	368-30
	1992	5	61-2	2.1-0.3	261-20
	1994	5	59-2	2.0-0.2	238-43
	1995	5	60-2	2.1-0.1	188-18
	1996	4	58-3	2.0-0.4	100-28
	SS 1996	5	56-1	2.9-0.3	124-9
	1997	4	58-3	1.6-0.1	100-37
	SS 1997	4	59-3	2.9-0.5	145-34
Beavermead	1982	4	73-3	4.1-0.8	369-145
	1985	5	68-3	1.6-0.5	641-74
	1986	5	65-6	2.5-0.4	342-42
	1987	6	52-3	1.9-0.5	210-90
	1988	4	68-3	3.8-0.4	215-133
	1989	5	65-2	2.6-0.4	370-72
	1990	6	61-3	2.0-0.9	266-48
	1991	5	62-1	2.3-0.2	200-20
	1992	5	59-2	1.6-0.3	182-18
	1994	5	61-1	1.7-0.3	148-18
	1996	5	57-2	1.6-0.3	72-23

Table 18: Total PCB residues in young-of-the-year yellow perch from the Otonabee River, Rice Lake and Seymour Lake from 1977 to 1997. Values are means ± standard deviation. (Spottail shiners (SS) were collected for comparison in 1996 and 1997).

STATION	YEAR	n	FISH LENGTH (mm)	LIPID (%)	PCB (ng/g)
Below STP	1980	6	82-2	4.5-0.3	1311-231
	1982	4	88-3	6.6-0.5	1034-121
	1985	2	73-2	2.8-0.2	1450-156
	1996	5	100-5	3.7-0.2	352-103
Above Bensfort Bridge	1989	3	67-3	3.1-0.4	477-150
Bensfort Bridge	1980	6	72-2	3.1-0.3	589-68
	1985	5	64-4	3.0-0.5	932-102
	1986	5	60-3	3.0-0.3	662-227
	1987	6	55-5	2.4-0.3	601-54
	1989	5	64-2	3.1-0.6	498-77
	1990	6	60-1	1.7-0.4	420-71
	1991	5	62-3	2.1-0.6	552-90
RICE LAKE					
Wallace Point	1987	6	52-1	2.0-0.2	257-59
Spook Island	1977	10	71-2	3.6-0.2	1383-100
	1978	8	68-2	2.5-0.2	1365-121
	1979	7	65-1	2.6-0.3	1373-96
	1980	6	78-2	1.8-0.2	609-116
	1981	7	69-3	2.1-0.3	801-109
	1984	5	72-3	2.9-0.2	878-73
	1985	4	66-6	2.4-0.5	1945-253
	1986	7	68-3	2.9-0.4	1139-75
	1987	6	54-4	1.9-0.3	485-50
	1988	5	64-2	2.6-0.2	478-275
	1989	6	65-1	3.0-0.3	720-176
	1990	7	61-2	1.9-0.2	679-124
	1991	5	63-3	2.2-0.6	1138-368
	1992	5	57-2	1.6-0.3	510-64
	1993	5	62-2	1.7-0.1	506-62
	1994	5	64-1	2.5-0.5	572-80
	1995	5	71-2	3.4-0.5	916-126
	1996	5	70-1	3.0-0.3	476-46
	SS 1996	5	59-3	2.9-0.2	348-59
	1997	5	68-1	2.5-0.3	504-62

Table 18: Total PCB residues in young-of-the-year yellow perch from the Otonabee River, Rice Lake and Seymour Lake from 1977 to 1997. Values are means ± standard deviation. (Spottail shiners (SS) were collected for comparison in 1996 and 1997).

STATION			YEAR	n	FISH LENGTH (mm)	LIPID (%)	PCB (ng/g)
Idywilde Point			1985	4	61-4	2.1-0.3	791-88
			1986	4	63-4	2.1-0.4	389-42
			1987	6	53-3	2.9-0.9	418-114
			1989	5	66-1	3.4-0.6	218-76
			1990	5	59-1	2.2-0.4	305-43
			1991	5	58-2	1.3-0.1	580-85
			1992	5	55-2	1.2-0.2	368-18
SEYMOUR LAKE							
Seymour Lake			1987	5	55-1	1.8-0.5	203-38
	Nappan Is.		1996	5	66-4	2.2-0.2	120-24
	Nappan Is.	SS	1996	3	60-2	2.2-0.4	87-23